THE ALASKA EARTHQUAKE, MARCH 27, 1964:
EFFECTS ON THE HYDROLOGIC REGIMEN

Hydrologic Effects of the Earthquake Of March 27, 1964 Outside Alaska

By ROBERT C. VORHIS

With Sections on

HYDROSEISMOGRAMS FROM THE NUNN-BUSH SHOE CO. WELL WISCONSIN

By ELMER E. REXIN and ROBERT C. VORHIS

and

ALASKA EARTHQUAKE EFFECTS ON GROUND WATER IN IOWA

By R. W. COBLE

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THE ALASKA EARTHQUAKE SERIES

The U.S. Geological Survey is publishing the results of investigations of the Alaska earthquake of March 27, 1964, in a series of six Professional Papers. Professional Paper 544 describes the effects of the earthquake on the hydrologic regimen. Other Professional Papers describe the history of the field investigations and reconstruction effort; the effect of the earthquake on communities; the regional effects of the earthquake; and the effects on transportation, communications, and utilities.

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HYDROLOGIC EFFECTS OF THE EARTHQUAKE OF MARCH 27, 1964, OUTSIDE ALASKA

By Robert C. Vorhis

ABSTRACT

The Alaska earthquake of March 27, 1964, had widespread hydrologic effects throughout practically all of the United States. More than 1,450 water-level recorders, scattered throughout all the 50 States except Connecticut, Delaware, and Rhode Island, registered the earthquake. Half of the water-level records were obtained from ground-water observation wells and half at surface-water gaging stations. The earthquake is also known to have registered on water-level recorders on wells in Canada, England, Denmark, Belgium, Egypt, Israel, Libya, Philippine Islands, South-West Africa, South Africa, and Northern Territory of Australia.

The Alaska earthquake is the first for which widespread surface-water effects are known. The effects were recorded at stations on flowing streams, rivers, reservoirs, lakes, and ponds. The 755 surface-water stations recording effects are spread through 38 States, but are most numerous in the south-central and southeastern States, especially in Florida and Louisiana. Most of the fluctuations recorded can be referred to more precisely as seismic seiches; however, a few stations recorded the quake as a minor change in stage. The largest recorded seiche outside Alaska was 1.83 feet on a reservoir in Michigan. The next largest was 1.45 feet on Lake Ouachita in Arkansas.

The largest fluctuation in a well was 23 feet registered by a pressure recorder near Belle Fourche, S. Dak. Fluctuations of more than 10 feet were reported from wells in Alabama, Florida, Georgia, Illinois, Missouri, and Pennsylvania. A 3.40-foot fluctuation was recorded in a well in Puerto Rico.

The Alaska earthquake was registered by about seven times as many water-level recorders as recorded the Hebgen Lake, Mont., earthquake of August 19, 1959.

INTRODUCTION

The hydrologic response to the Alaska earthquake of March 27, 1964, was the most widespread of all previously registered seismic events. Some 716 wells in the United States recorded water-level fluctuations caused by the quake. Outside the United States, wells in Canada, England, Belgium, Denmark, Libya, Israel, South-West Africa, South Africa, and Australia recorded the earthquake. This worldwide response results from the great magnitude of the quake—the largest to occur in North America in this century. Of the previous large earthquakes recorded widely in the United States, the Assam, India, earthquake of August 15, 1950, affected at least 161 wells, and the Hebgen Lake, Mont., earthquake of August 17, 1959, was recorded in 185 wells.

Another important response was registered as water-level fluctuations on streams, reservoirs, ponds, and lakes. At most of the gaging stations the charts show upward and downward motions that were about equal and that generally recovered to a normal level within a few minutes. On some lakes and reservoirs the fluctuations continued for an hour or more.

A third effect caused by the earthquake was roiling or muddying of well and spring water. This phenomenon, when reported by well users, generally occurred in wells that required long-continued pumping to clear the water at the time the well was drilled. The roiling is presumably limited to wells and springs tapping aquifers that contain considerable colloidal material.

The purpose of this report is to assemble the hydrologic effects of the Alaska earthquake that were recorded outside Alaska. The nature and geographic distribution of the hydrologic effects are described, the seismic fluctuations in water wells in the United States are tabulated, and data on seismic seiches in North America and well fluctuations outside the United States are summarized. Thus, the report is a compilation of both published and unpublished data on known hydrologic effects throughout the world. Furthermore, a background of previous work, a discussion of several water-level recording instruments, and observations of fluctuations during other earthquakes are presented in order to provide a suitable basis for future interpretive studies. It is hoped that this framework will encourage further studies so that the discrepancies that exist between earthquake theory and observed effects can be narrowed and ultimately bridged.

DEFINITION OF TERMS

The term "hydroseism" is here introduced as convenient to include all seismically induced water-level fluctuations other than tsunamis. Although this type of fluctuation has been described in many previous papers, no one term nor one phrase has been used consistently. Terms and phrases which have been used to describe hydroseisms in wells include:

1. Pressure fluctuations produced by seismic waves.
2. Seismically induced fluctuations of water level.
3. Water-level fluctuations.
4. Earthquake-induced fluctuations.
5. Fluctuations in well water levels (the title under which hydroseismic data have been published annually in the U.S. Coast and Geod. Survey series "United States Earthquakes").

The following terms have been used to describe hydroseisms in surface-water bodies:

1. "Disturbances [as recorded] at stream-gaging stations" (U.S. Coast and Geod. Survey, 1946, p. 26).
2. "Range of stage recorded in stilling wells * * * as the result of earth tremors" (Stermitz, 1964, p. 144).
3. Seismic seiches.

The term "hydroseism" is derived from the Greek words *υδωρ* meaning water and *σεισμος* meaning earthquake. As defined and used in this report, hydroseism applies to seismically induced fluctuations in wells, streams, lakes, ponds, and reservoirs. As such, it is identical in meaning with any and all of the expressions listed above.

"Hydroseismic data" includes both the charts that record hydroseisms and the information taken from the charts.

"Hydroseismogram" is a hydroseism recorded at an expanded time scale.

"Seiche" is a term first used in Switzerland by Forel (1895) to apply to standing waves set up on the surface of Lake Geneva by wind and by changes in barometric pressure. Richter (1958, p. 109) points out that seiches may occur not only in closed bodies of water but also in partially closed bodies such as harbors or channels and as lateral oscillations in rivers, canals, or ditches. It is only necessary that the geometry of the water boundary define a natural period of oscillation. Where there are currents, part of a seiche may be transformed into a progressing wave.

To restrict the term "seiches" to those events caused by earthquakes, Kvale (1955) qualified the phenomenon as seismic seiches. Following his usage, in this paper "seismic seiches" refer to symmetrical fluctuations (that is, those fluctuations where the water-level rise is exactly equal to the water-level decline) typical of standing waves set up on rivers, reservoirs, ponds, and lakes at a time corresponding with the passage of seismic waves from the Alaska earthquake. Where the record does not correspond to what would be expected from a standing wave, the more general term "hydroseism" is used.

ACKNOWLEDGMENTS

The material on which this report is based has come from many sources and has been the work of hundreds of persons engaged in various aspects of water-resource investigations. Most of these people are known to the writer only by their affiliation with the organization which transmitted the data.

The following organizations outside the United States have furnished data on hydrologic effects of the Alaska earthquake in their countries, and their help is gratefully acknowledged:

- Geological Survey of Canada
- Canadian National Committee for the International Hydrologic Decade
- Canada, Ontario Water Resources Commission
- Canada, Saskatchewan Department of Agriculture

United Kingdom of Libya, Ministry of Agriculture
State of Israel, Hydrological Service of Ministry of Agriculture
South-West Africa, Geological Survey
Republic of South Africa, Geological Survey
Commonwealth of Australia, Northern Territory Administration
New South Wales, Snowy Mountains Hydro-Electric Authority
Victoria, State Electricity Commission
Belgian Ministry of Public Works, Hydraulic Research Laboratory
United Kingdom, Geological Survey and Museum, Water Department
Denmark Geological Survey
Republic of the Philippines, Bureau of Public Works
United Arab Republic, U.S. AID Mission

Most of the records of hydroseisms in the United States were compiled and sent to the author by members of the Water Resources Division of the U.S. Geological Survey. The following organizations in the United States have also made their records and data available for use, and the author is grateful to them for this help:

Orange County [Calif.] Water District
Los Angeles County [Calif.] Flood Control District
Idaho Bureau of Mines and Geology
Illinois State Water Survey
Gas storage companies in Illinois, Iowa, and Ohio
Missouri Geological Survey and Water Resources
Division of Water, Ohio Department of Natural Resources
Tennessee Department of Conservation, Division of Water Resources
Virginia Geological Survey

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The author is also grateful to the many organizations which examined their recorder charts for the period of the Alaska earthquake and verified that no fluctuations caused by the earthquake had been recorded. The countries and names of the organizations in which recorded charts were found to show no apparent reaction to the quake are the following:

Afghanistan:
- Water and Soil Survey Authority
- U.S. AID Mission

Australia:
- Sydney Metropolitan Water, Sewerage, and Drainage Board
- Irrigation and Water Supply Commission
- South Australia Engineering and Water Supply Department
- South Australia Director of Mines
- Victoria Rivers and Water Supply Commission

Austria:
- Hydrografisches Zentralburo.

British Guiana: Geological Survey Department
Cyprus:
- Ministry of Commerce and Industry
- Geological Survey Department

Denmark: Meteorological Institute
Ethiopia: Water Resources Department
Ghana: National Construction Corp.
Greece: Institute for Geology and Subsurface Research
Hungary: Research Institute for Water Resources
Jamaica: Geological Survey Department
Indonesia: Geological Survey
Kenya: Water Development Department
Mozambique: Service for Geology and Mines
Nepal:
- Hydrological Survey Department
- U.S. AID Mission

Netherlands: Archives of Ground-Water Levels
New Guinea: Australia Department of Public Works
New Zealand:
- Ministry of Works
- Geological Survey

Nigeria:
- Geological Survey
- U.S. AID Mission

Norway: Water Resources and Electricity Board
Papua: Australia Department of Public Works
Portugal: Geological Survey
Rhodesia:
- Ministry of Water Development, Hydrological Branch
- Ministry of Mines and Lands, Geological Survey Office

Saudi Arabia: Ministry of Petroleum and Mineral Resources
Spain: Institute of Geology and Mines
Sudan: Geological Survey
Switzerland: Federal Office for Water Economy
Syria: Ministry of Industry
Taiwan: Geological Survey
Tasmania:
- Rivers and Water Supply Commission
- Hydro Electric Commission

Turkey: State Hydraulic Works
Uganda: Water Development Department
Union of Soviet Socialist Republics: Hydrometeorological Service
Zambia: Ministry of Lands and Natural Resources

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PREVIOUS INVESTIGATIONS

Hydrologic effects of earthquakes have been previously compiled from observation wells and at surface-water gaging stations. In some studies, recorders with expanded time scales have been operated to ascertain the types of seismic waves that produce hydrologic effects. The Richter scale of earthquake magnitudes has been applied to hydroseisms, and theoretical studies have been developed to account for hydrologic responses to seismic waves. No single study, however, has considered both the effects recorded by observation wells and those recorded at surface-water gaging stations.

HYDROSEISMS IN WELLS

Data on hydroseisms in wells are published annually by the U.S. Coast and Geodetic Survey (1945, 1946, 1951–65). The years for which these data are now available include 1943, 1944, and 1949 through 1963. Only one publication (da Costa, 1964) lists hydroseisms in wells throughout the United States from a single major earthquake, the Hebgen Lake, Mont., earthquake of August 17, 1959.

Other published reports describe hydroseisms that have been recorded in a single well. Parker and Stringfield (1950, p. 456–458) list earthquakes and their hydroseisms as recorded in a limestone well at Miami, Fla. Eaton and Takasaki (1959) made a similar study of a well in basalt at Honolulu, Hawaii, and were the first to attempt to correlate earthquake magnitudes with hydroseismic data. Vorhis (1964a), using the same approach, made a study of hydroseisms recorded in a well penetrating crystalline rocks in Dawson County, in the Piedmont of northern Georgia.

Hydroseisms from one or a few selected earthquakes as recorded in wells scattered through a rather restricted geographic area have been described in many publications: Austin (1960) for wells in New Jersey; Davis, Worts, and Wilson (1955) for hydroseisms in California wells caused by the Kern County earthquake of 1952; Hopkins and Simpson (1960) for the effects of the Hebgen Lake earthquake in mine-water pools in Pennsylvania; LaMoreaux (1953) for the effects in Alabama wells of the Kamchatka earthquake of November 4, 1952; LaRocque (1941) for hydroseisms in California wells caused by five different quakes from 1933 to 1940; Leggette and Taylor (1935) for hydroseisms in Utah wells; Piper (1933) for hydroseisms recorded in the Mokelumne area of California from the December 20, 1932, earthquake at Lodi, Calif.; Piper, Thomas, and Robinson (1939) for later hydroseisms recorded in the Mokelumne area of California; Stearns (1928) and Stearns, Robinson, and Taylor (1930, p. 145–151) for hydroseisms in California wells; Stewart (1958) for hydroseisms in Georgia wells; Thomas (1940) for hydroseisms recorded in California by earthquakes of November 10, 1938 (in Alaska), and January 24, 1939 (in Chile); and Vorhis (1955) for hydroseisms in a Wisconsin well.

The theoretical effect of earthquake waves on a water well was originally studied from a seismological point of view by Blanchard and Byerly (1935). A reexamination of this theory was made by Rexin, Oliver, and Prentiss (1962) who related the magnification in the well to the period of the seismic surface waves causing the fluctuation. The Alaska earthquake reawakened interest in the subject. Subsequent reports hold much promise for providing a theoretical understanding of hydroseismic data. Papers containing a development of theory with emphasis on the hydrologic controls have been prepared by Cooper and others (1965) and Bredehoeft and others (1965). The Richter scale of earthquake magnitudes has been applied to hydroseisms (Eaton and Takasaki, 1959; Vorhis, 1964a, 1965a), but the many variables relating to a well, to earthquake waves, and to their travel paths prevent a rigorous application of this method, at least for the present.

Hydrologic effects of the Alaska earthquake have been discussed or mentioned in many publications. Fluctuations in Canadian wells were described for Alberta by Gabert (1965) and for Ontario and Saskatchewan by Scott and Render (1965). Widespread hydrologic effects of the quake as recorded in the United States were published by Peterson (1964), Waller, Thomas, and Vorhis (1965), and Vorhis (1964b, 1965b). Local hydrologic effects within the United States were discussed by Coble (1967), Fellows (1965), Fuller (1964), Wilson (1964), Hassler (1965), Miller and Reddell (1964), The Cross Section (1964), Mills (1964), Rexin (1963, 1964a, b), Cooper and others (1965), and Bredehoeft and others (1965).

HYDROSEISMS ON SURFACE-WATER BODIES

Earthquake effects on river gages were first mentioned by Piper (1933, p. 475, fig. 2). Two of six gages on the Mokelumne River in California showed pronounced dots on the traces of the water surface that were caused by the December 20, 1932, earthquake at Lodi, Calif. Two other gages on a nearby diversion canal showed double amplitudes of 0.08 and 0.04 foot for the same quake. Although they were not designated as such by Piper, they can properly be called seismic seiches.

The U.S. Coast and Geodetic Survey (1946, p. 26) lists 18 "Disturbances at stream-gaging stations in New York on September 5, 1944, from an earthquake in the St. Lawrence Valley." Most of these may be seismic seiches but, not knowing whether they are standing waves, it seems safer to refer to them as hydroseisms.

For the Hebgen Lake earthquake of August 17, 1959, Stermitz (1964, p. 144, table 10) lists 54 records for "Range of stage recorded in stilling wells * * * as the result of earth tremors."

The hydroseisms mentioned above were all recorded within a few hundred miles of the epicenter of the quakes. In Stermitz's list, the most distant event recorded was 340 miles northwest of the epicenter. The events discussed below are unusual in that they were recorded thousands of miles distant from the epicenter.

Kvale (1955) discusses seismic seiches in 29 fiords and lakes in Norway caused by the Assam earthquake of August 15, 1950, but does not mention that any seiches were recorded in rivers.

Seismic seiches from the Alaska quake, recorded on the west coast of Canada in lakes, rivers, and tidal waters, are mentioned by Wigen and White (1964a, b). Some seismic seiches on rivers and lakes in central Canada are described by Strilaeff (1964).

Donn (1964) mentions reports of waves as much as 6 feet high on the gulf coast caused by the Alaska earthquake. He suggests that these waves and the fluctuations on the Freeport, Tex., tide gage are probably seismic seiches generated in resonance with the seismic waves.

McGarr (1965) formulated a theory to explain the generation, occurrence, and damping of seismic seiches. The theory was then applied to a marigram at Freeport, Tex., that showed the Alaska earthquake.

Thus, seismic seiches represent a type of hydroseism that has received little attention previously, especially such seiches recorded in rivers.

HYDROSEISMIC DATA

TYPES OF WATER-LEVEL RECORDERS AND CHARTS

The water-level recorders currently in operation on observation wells throughout the United States meet a wide variety of needs; they are adapted to fit all types of well construction, are selected to fit economical servicing schedules, and must respond to many different ranges in water-level fluctuation. As a result, each well tends to give a record characteristic of itself. Consequently, when charts from many wells are gathered as they have been in this study, they present an amazing variety of records.

The hydroseismic data on water-level recorder charts are affected by the time scale and the vertical or gage-height ratio. Those recorders equipped with 1:30, 1:24, and 1:12 gage-height gears are most likely to record the extreme upper and lower limits of the fluctuation. Those recorders with 1:1 and 1:2 ratios are most likely to record the aftershocks. Thus there is no one ratio that is best for recording hydroseisms. Those recorders with a time scale of 2.4 inches per day are more likely to show hydroseismic detail than are those with a time scale of 0.3 inch per day.

Of the 716 wells for which data have been tabulated, copies of charts from 433 wells showing the earthquake record have been received by the author. Of these, 12 were from pressure recorders and 421 were from float-type recorders. Table 1 (next page) shows the various gage-height ratios and time scales at which these 421 records were made. The gage-height scale is chosen to give a record that minimizes "background noise" such as pumping effects and tides, and emphasizes water-level trends. The time scale is chosen primarily to get the

TABLE 1.—*Gage-height ratio and time scales of 421 float-type recorders that registered the Alaska earthquake*

Gage-height ratio	Recorder time scale, in inches per day							
	0.3	1.0	1.2	1.8	2.3	2.4	9.6	576
1:30						3		
1:24			1					
1:12	2		19			9		
1:10	28		20		3			
1:6	2		39			58		
1:5	54	2	10			1		
1:3			2			1		
1:2.4				4		2		
1:2	50							
1:1.2	1					8		
1:1	73	1	20		5	1	1	
5:1								1

maximum of record with a minimum cost. From the recorders operating with a time scale of 2.4 inches per day, the arrival time of a seismic disturbance can be determined at best to the nearest 10 minutes. For recorders operating at 1.2 inches per day, time can be read only to the nearest 20 minutes. On recorders operating at 0.3 inch per day it is extremely difficult to determine a time closer than 1 to 2 hours.

The time-compressed record of water-level recorders in normal use has prompted the development and operation of several recorders operating at a greatly expanded time scale. Blanchard and Byerly (1935, 1936; Byerly and Blanchard, 1935) were the first to install such a recorder. By maintaining it on a well in California, they were the first to obtain a hydroseismic record similar to a seismogram. From it, they identified several types of waves (P, PP, PPP, S, L, and M).

Since 1947, an expanded-scale water-level recorder has been developed and maintained by E. E. Rexin on a well at Milwaukee, Wis. Details on this instrument have been published previously (Rexin, 1952, 1960; Rexin, Oliver, and Prentiss, 1962), and a few of the records have received detailed seismological study. Through this, Rexin, Oliver, and Prentiss (1962) identified nine types of waves additional to those reported by Blanchard and Byerly. These waves were PKS, SKS, PS, PPS, SS, SSS, LQ, LR_1, and LR_2. This recorder was in operation at the time of the Alaska earthquake, and its hydroseismogram is the only one known from this earthquake. The record is discussed in "Hydroseismograms from the Nunn-Bush Shoe Co. well," (p. C10).

In recent years the Rensselaer Polytechnic Institute has built and operated expanded-scale recorders on several shallow and deep wells in New York State as part of a research program in explosion detection (Katz, 1961, 1962, 1963; Katz, Carragan, and Michalko, 1962a, b; Carragan, Katz, and Michalko, 1963; and Carragan, Michalko, and Katz, 1964). Their work is of great interest, and the equipment they assembled is the most advanced of any used at present. Lack of funds caused operation of these recorders to be discontinued shortly before the Alaska earthquake.

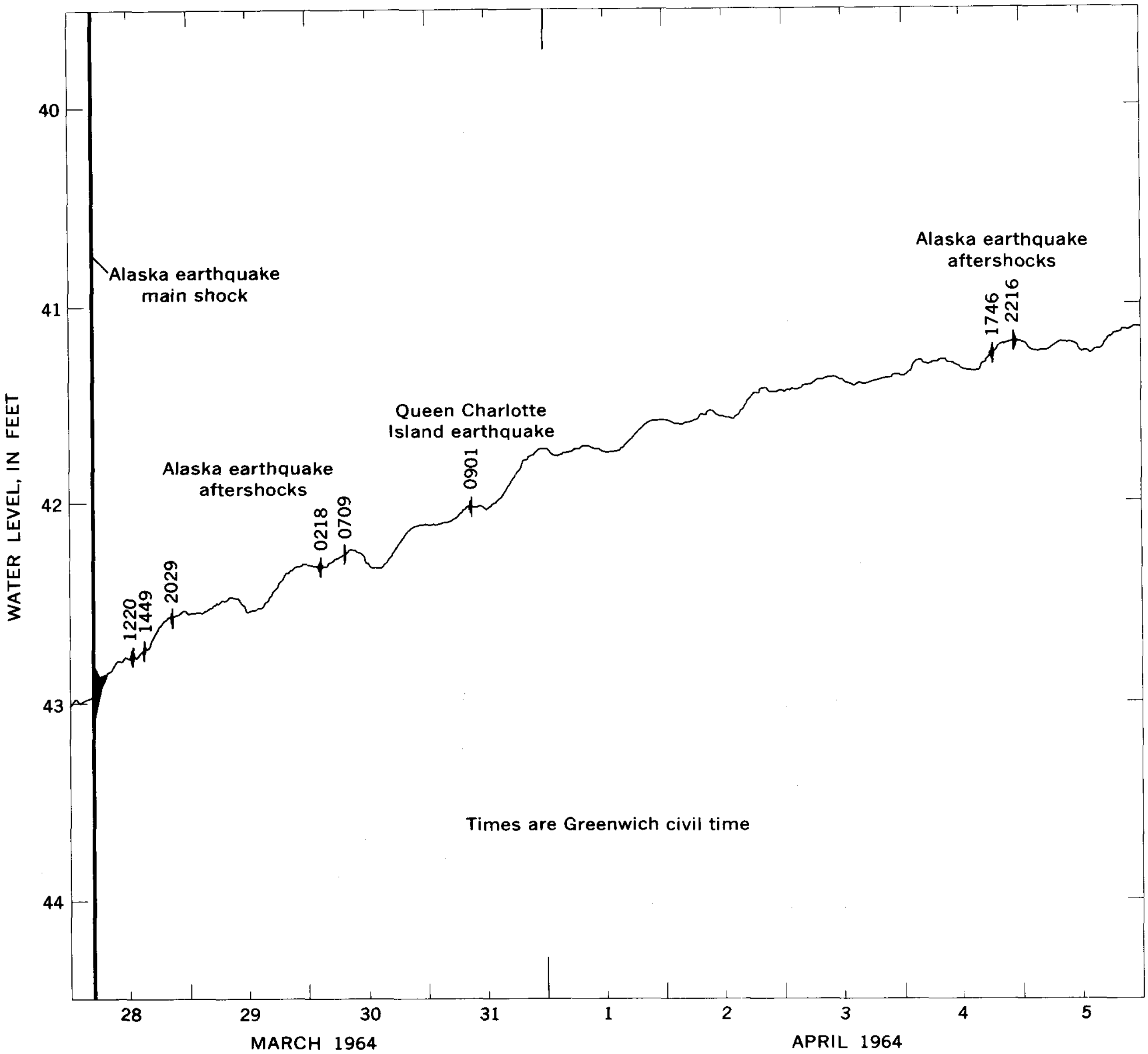
The U.S. Geological Survey operated sensitive expanded-scale recorders on a well in Arizona and a well near St. Augustine, Fla., but lack of funds caused operation to be discontinued about a month before the Alaska earthquake. No data obtained from these recorders have been published.

RECORDABLE HYDROSEISMIC DATA

HYDROSEISMS IN WELLS

The water-level recorders currently maintained on observation wells can at best record only limited data from any seismic event. Recordable hydroseismic data include the following:

1. The depth to water in the well at the start of the seismic record.
2. The maximum seismically caused water-level rise.
3. The maximum seismically caused water-level decline.
4. For the largest seismic events, some wells record a coda portion during a period of 1–2 hours following the maximum fluctuation during which the fluctuations decrease to static level.
5. In especially sensitive wells, the surface wave that took the long way around the world (the W_2 wave) may record as a distinct fluctuation, and, likewise, the wave traveling in the opposite direction (the W_3 wave) may record as a still smaller but distinct fluctuation. These waves have been identified for the first time on records from the Alaska earthquake.
6. A change in water-level trend due presumably to seismically caused changes in the aquifer such as increase or decrease in transmissibility and enlargement or contraction of fractures.
7. The water level at the end of the seismic disturbances,

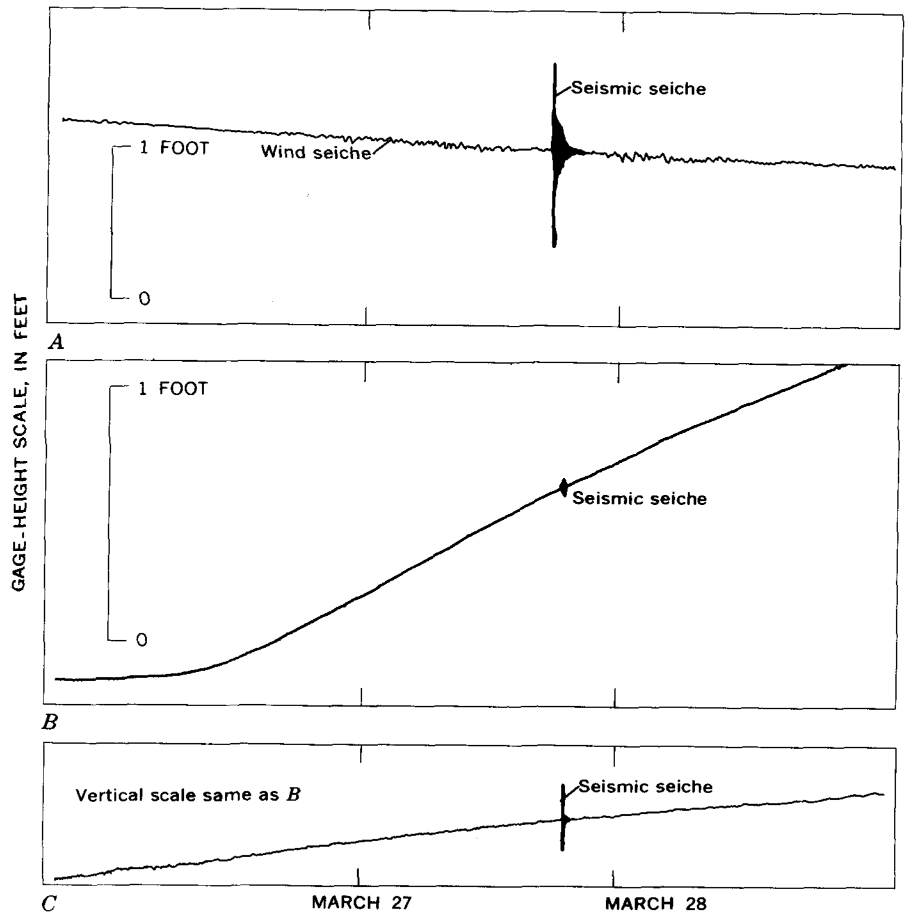


1.—Hydroseismic chart of a well in Mitchell County, Ga.

which may be quite different from the level at the start for any of a number of reasons: Seismically induced change in aquifer stress, change in barometric pressure, change in tidal cycle, pumping effects, or recharge.

8. The approximate time of the disturbance.

One of the more detailed hydroseismic charts (fig. 1) shows the very large fluctuation of water level that occurred due to the Alaska earthquake, seven aftershocks, and the Queen Charlotte Island earthquake of March 31. On the type of recorder in operation, the pen reverses when it reaches the edge of the chart, so the size of the fluctuation is known to have been in excess of 5 feet with at least 3.5 feet presumably accounted for in the rise. Because many wells tend to have a water-level rise equal to the decline, it is reasonable to assume that water in this well fluctuated more than 7 feet. From examination of this chart, one can see how relatively



2.—Typical records of hydroseisms caused by the Alaska earthquake. *A*, Record at Blakely Mountain Dam on Lake Ouachita, Ark. Record furnished by U.S. Corps of Engineers. *B*, Record at Castor Creek near Grayson, La. *C*, Record at St. Francis River at Marked Tree, Ark. Central standard time.

few data can be taken from any one chart. From the above list of possible data that can be recorded, only items 1, 4, 7, and 8 can be read from the record shown in figure 1.

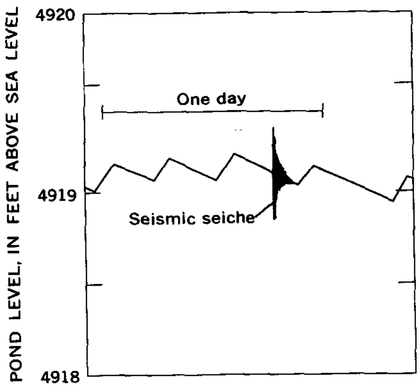
The most detailed of all the hydroseismic records are from the Nunn-Bush Shoe Co. well in Milwaukee, Wis. From March 27 to 30, the water levels fluctuated in response to the arrival of P, S, and L waves from the Alaska earthquake and aftershocks. The records (figs. 8, 9) are discussed in detail on page C10.

HYDROSEISMS FROM SURFACE-WATER GAGES

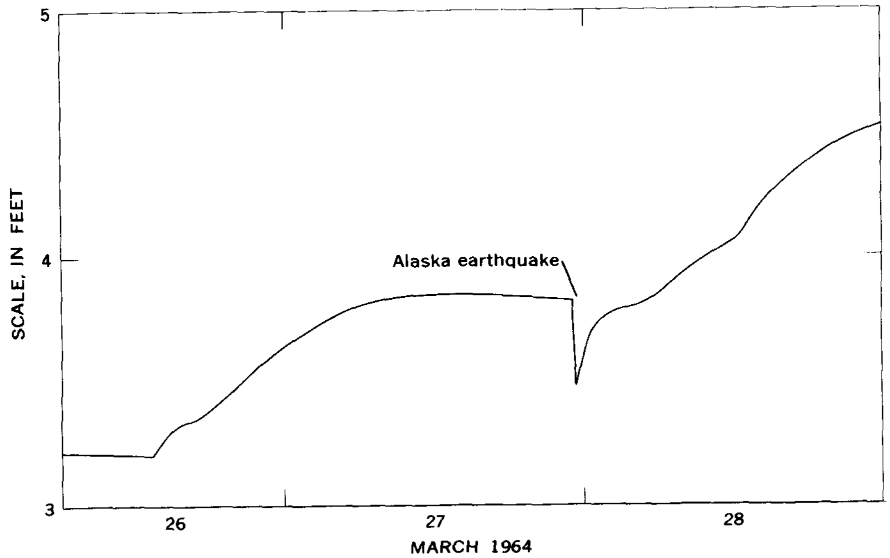
SEISMIC SEICHES

Most of the 753 surface-water hydroseisms were recorded as seismic seiches. Included in this category are the fluctuations starting with a maximum oscillation that gradually diminished to a steady water level (fig. 2*A*). A variant type includes some seiches that began with a small oscillatory rise and fall, increased with time, and then died back to normal (fig. 2*B*). Another variant is a sudden rise and fall of water level consisting of only one or a few oscillations. That the number of oscillations is small is known from the narrow width of the pen line on the chart (fig. 2*C*).

One of the largest of the seismic seiches was recorded by the U.S. Corps of Engineers on Lake Ouachita in Arkansas at the Blakely Dam Headwater Gorge (fig. 2*A*). This record shows 1.45 feet of fluctuation gradually diminishing to "normal" over about 2½ hours.



3.—Hydroseism caused by the Alaska earthquake, recorded at the disposal pond of the National Reactor Testing Station, Idaho.



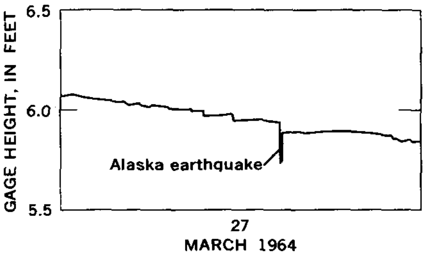
4.—Seismically induced decline in stage at Little Haw Creek near Seville, Fla. Eastern standard time.

One of the best recorded seiches was from a pond at the National Reactor Testing Station in Idaho (fig. 3). Although the seiche had a maximum rise and fall in water level of only 0.56 foot, the oscillations continued over a period of 2 hours. The pond bottom is in alluvial sand and gravel of the Big Lost River. The sand and gravel overlie basalt. This geologic setting seemingly is favorable for the generation of a seismic seiche in the pond.

SEISMICALLY INDUCED CHANGE IN STAGE

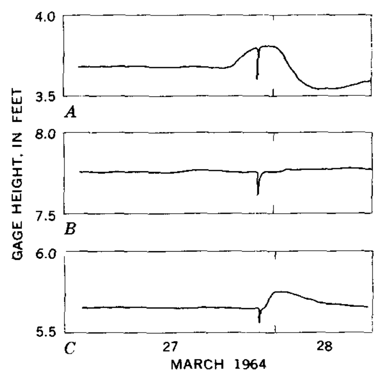
An unusual record is the one from Little Haw Creek near Seville, Fla. (fig. 4). At the time the seismic waves reached the gage, the water stage began to decline and dropped 0.33 foot in about 15 minutes. Then the trend reversed and the water level began to rise.

Another unusual record was obtained on Tensas River at Tendal, La. (fig. 5). The water level suddenly declined 0.20 foot, then rose only 0.15 foot and remained level for 7 hours even though the trend before and after the quake was a slow steady rise. Because the bubbler-type gage on which this was registered has a built-in delay, rapid fluctuations do not record. The first motion detected by the instrument was a water-level decline.



5.—Bubbler-gage record of Alaska earthquake for Tensas River at Tendal, La. Central standard time.

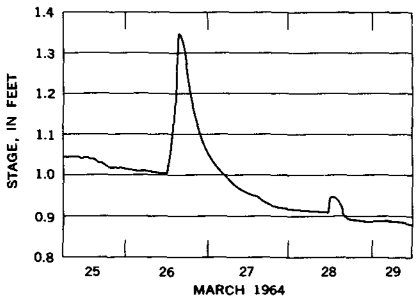
Three surface-water recorders in Kansas also registered the quake as a temporary decline in stage. A small sharp decline in water level was followed by a slightly less rapid rise to the preearthquake level (fig. 6). Inasmuch as all three charts were recorded by bubbler gages, the traces may not represent a true decline in stage. The author has not yet been able to establish whether rise or fall is related either to the location of the gage on the cross section of the stream or to the seismic waves.



6.—Bubbler-gage records of the Alaska earthquake from Kansas. *A*, Big Blue River near Manhattan. *B*, Neosho River near Chanute. *C*, Neosho River near Burlington. Central standard time.

SEISMICALLY INDUCED FLOW(?)

Among the 755 charts examined, only one appears to show what may be seismically induced flow. The hydrograph from March 25–29, 1964, of Paxton Creek in Pennsylvania shows (fig. 7) the effect of a rain in the basin on March 26. On March 28 a smaller rise



7.—Stage of Paxton Creek, Pa., showing increased flow on March 26 from 0.36-inch rainfall and possible seismically induced discharge from an aquifer on March 28, 1964. Eastern standard time.

is shown, but the rise seems quite rapid and is followed by a gradual decline to or below the preearthquake trend. There was no known rainfall that could have caused this rise. The time is inconclusive, for the rise occurred 13 hours after the earthquake. This increased flow has been interpreted by Louis Carswell (oral commun., September, 1964) as reflection of a slug of ground water squeezed out of an aquifer into the creek some miles upstream. If this supposition is true, the slug then retained its identity for 13 hours during its travel to and past the gage.

The hydrologic effects recorded at surface-water gages, although far smaller in size than many of the hydroseisms in wells, are of interest because they are so unusual. Never before, to the author's knowledge, have seismic seiches been reported in flowing streams at great (teleseismic) distances from an epicenter.

HYDROSEISMOGRAMS FROM THE NUNN-BUSH SHOE CO. WELL, WISCONSIN

By Elmer E. Rexin and Robert C. Vorhis

The most detailed of all hydroseismic records of the Alaska earthquake are from the Nunn-Bush Shoe Co. well in Milwaukee, Wis. These were obtained from a recorder built and maintained on the well by Rexin. The recorder operates with a chart speed of 576 inches per day and magnifies the fluctuations to five times their natural size.

The well, which is at Fifth and Hadley Streets in Milwaukee, was drilled in 1925. It has a 10-inch casing with welded joints to a depth of 107 feet, an 8-inch casing from 104 to 215 feet, and an 8-inch open hole from 215 feet to the bottom at 400 feet.

The artesian aquifer penetrated by this well is formed by the Waubakee and Niagara Dolomites of Silurian age. This aquifer characteristically is not uniformly permeable, and water occurs chiefly in joints and along bedding planes.

On the night of March 27, 1965, as the watchman marked 22:00 hours on the chart of the water-level recorder, he found that something quite violent was being recorded. He immediately called Rexin to report that the float was banging down in the well, the water was gurgling, and the pen was flying back and forth from end to end of the recording drum.

The senior author arrived 20 minutes later and verified that the chart (fig. 8) was recording a major earthquake. The preliminary movement was recorded at 21:43:20 c.s.t., March 27 (03:43:20 G.c.t., March 28) with a clear and distinct initial drop in water level of 0.005 foot. Movement continued small and somewhat indecisive for 2½ minutes, then the water level quickly rose 0.034 foot. This was followed by a decline, and rhythmical movements were recorded for the next 4½ minutes. Then movement became more violent (apparently owing to arrival of the S wave) for a period of less than a minute. A lesser motion (in the sense that the motion was barely within the recording limits of the instrument) followed for a 3-minute period. Immediately thereafter the water level began to fluctuate so violently that the range of movement exceeded the limits of the recorder. The period of these violent fluctuations was about 15 seconds each. The maximum movement during this phase could not be measured but was estimated to have been about 12–14 feet.

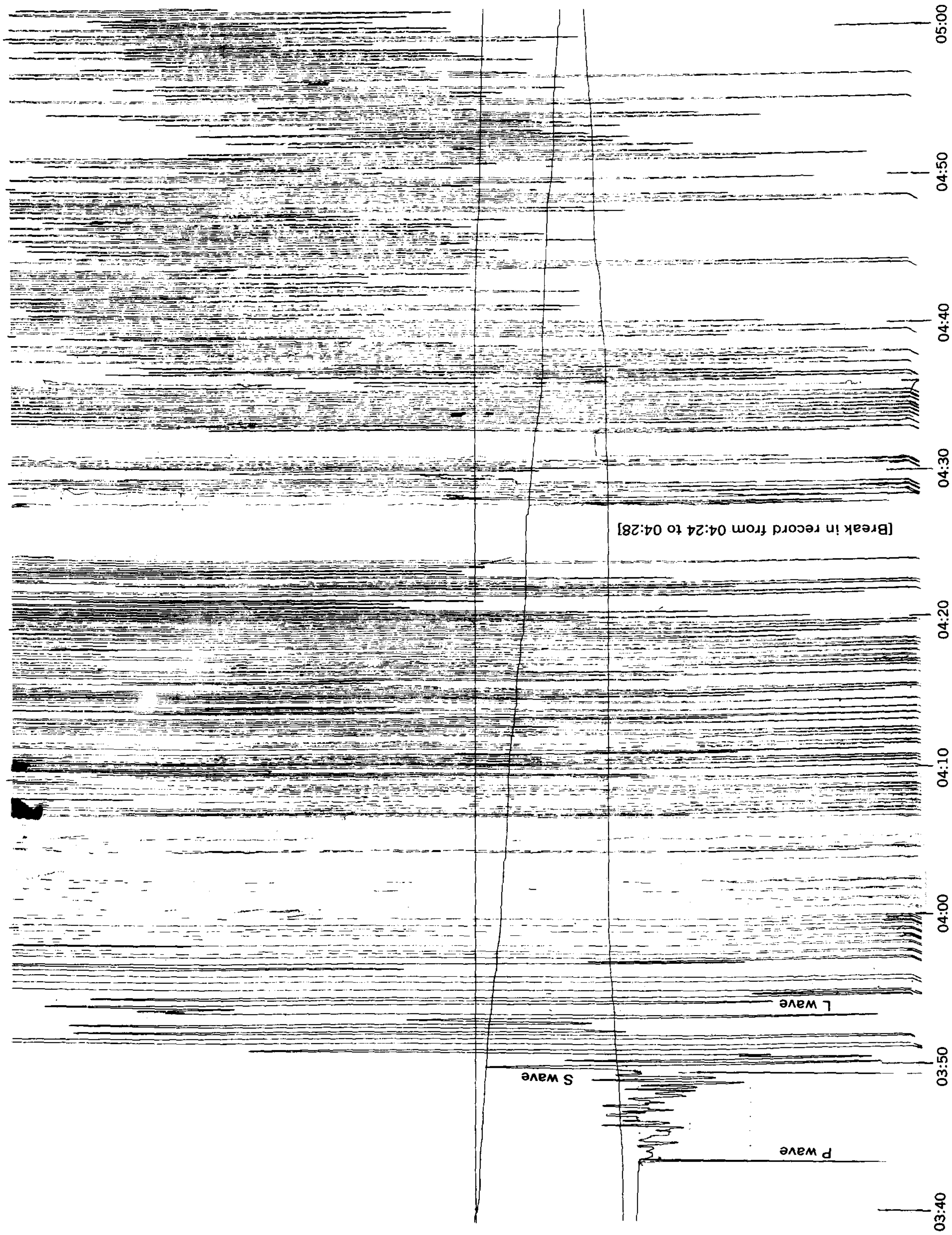
Large waves with periods measured in minutes, in addition to the 15-second waves, are suggested if one sketches in a line that connects the midpoints of fluctuations. The more significant details shown on these hydroseismograms (figs. 8, 9) are tabulated below (table 2) along with the epicentral times of the quake and the aftershocks that were recorded.

The hydroseismograms from this well are truly unique in that they are the only expanded-scale records showing in detail the effect of the Alaska earthquake on water levels. As such, they will undoubtedly be subjected to much detailed study in the years ahead. Rexin's observations of the many earthquakes recorded in this well have shown that the long-period waves such as followed the Alaska quake are invariably associated with major earthquakes that also generate tsunamis. He believes that this aspect may have an importance in itself that will make further study worthwhile.

Table 2.—*Chronological list of hydroseismic data from the Nunn-Bush Shoe Co. well at Milwaukee, Wis., March 28–30, 1964*

[Greenwich civil time]

March 27, 1964	
20:20	Measured depth to water was 99.20 feet.
March 28, 1964	
03:36:13	[Time of Alaska earthquake, at epicenter.]
03:43	Arrival of P wave (fig. 8).
03:49	Arrival of S wave (fig. 8).



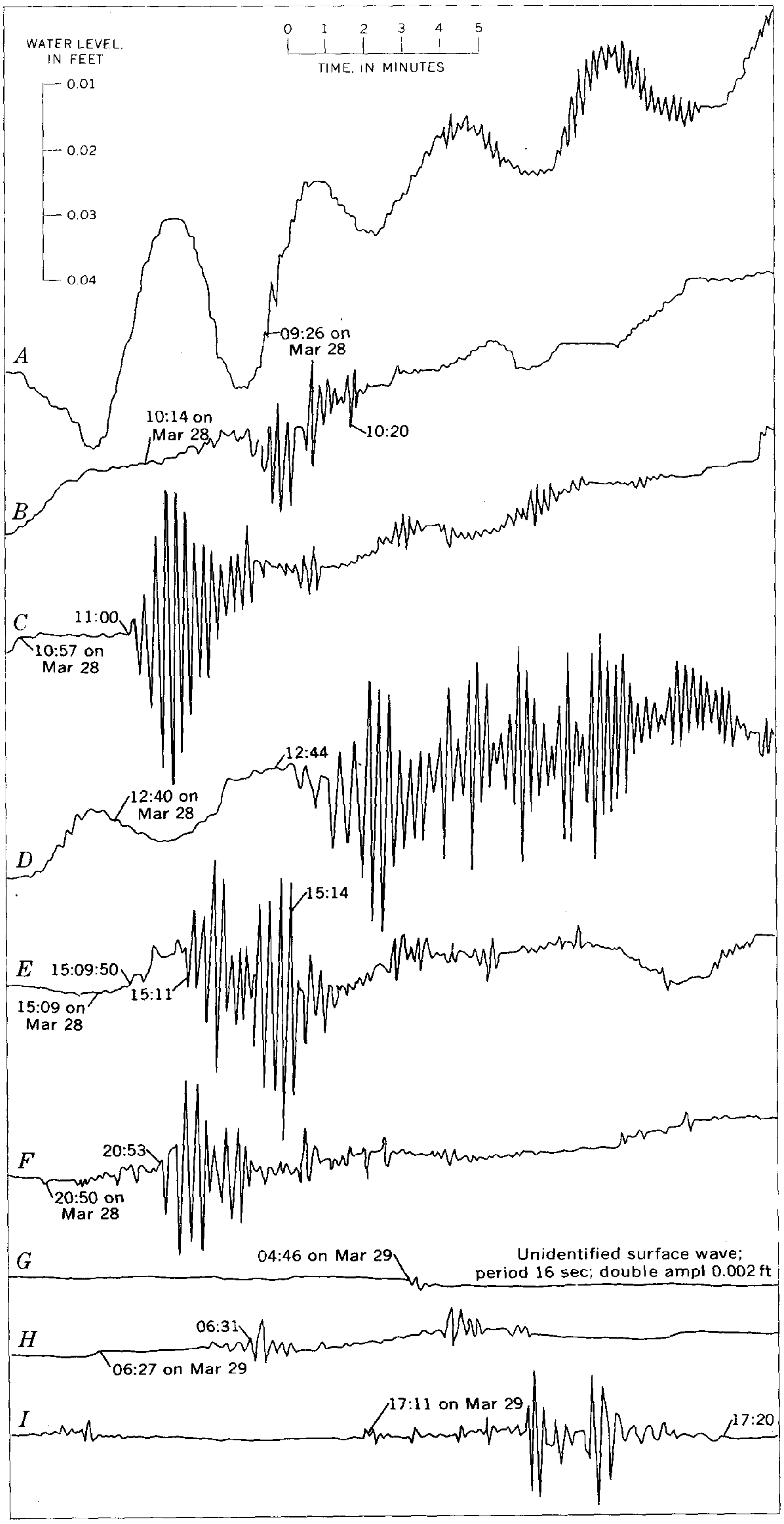
8.—Hydroseismogram of Alaska earthquake as recorded in Nunn-Bush Shoe Co. well at Milwaukee, Wis.

229-356 O—66——3

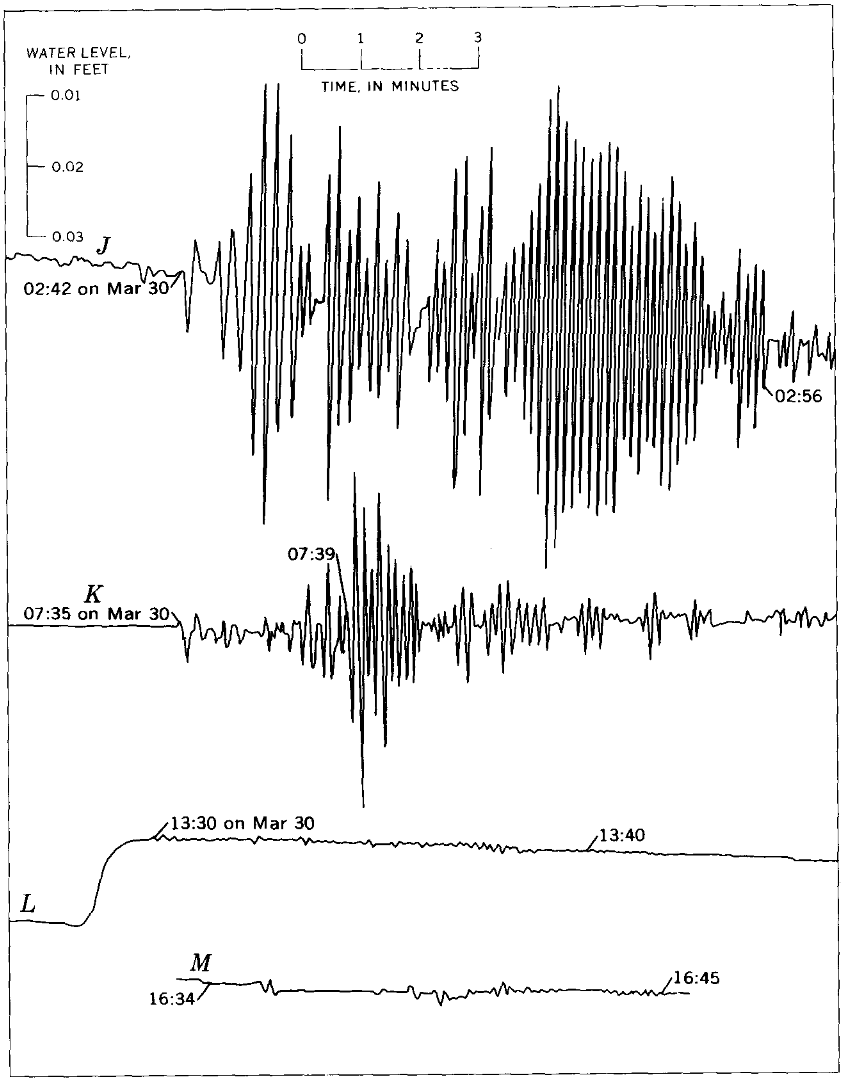
TABLE 2.—*Chronological list of hydroseismic data from the Nunn-Bush Shoe Co. well at Milwaukee, Wis., March 28–30, 1964*—Continued

March 28, 1964—Continued

03:52	Start of L(?) wave (fig. 8).
03:55	Start of major water-level oscillations.
04:24	Pen ran out of ink and had to be refilled.
04:28	As recording resumed, the oscillations began to decrease in amplitude. The record suggests that there was a "superwave" of about 24 minutes in period and, as the record continued, the period gradually lessened to about 4 minutes.
05:12	Water level began a slow steady rise that continued to 11:18 G.c.t. and, as measured from the charts, represents a minimum rise of 1.64 feet.
06:17	A distinct water-level rise and decline that occurred over a 2½-minute interval. End of chart 1.
09:26	Start of distinct train of 16-second waves with maximum double amplitude of 0.008 foot superimposed on long continuing waves of 4-minute period (fig. 9*A*).
09:52:54	Aftershock of magnitude 6.2 (as determined at Pasadena, Calif.).
10:14½–10:20	Record of aftershock, with wave of 16-second period and maximum double amplitude of 0.016 foot (fig. 9*B*).
10:35:39	Aftershock of magnitude 6.3 (Pasadena).
11:00	Aftershock recorded as a distinct train of 18-second waves



9.—(above and on p. C13).—Hydroseismograms of aftershocks of the Alaska earthquake recorded in the Nunn-Bush Shoe Co. well. Greenwich civil time.



March 28, 1964—Continued

	with maximum double amplitude of 0.046 foot (fig. 9*C*).
12:20:48.8	Aftershock of magnitude 6.5 (Pasadena).
12:44–13:02	Aftershock recorded as a distinct train of 18-second waves with maximum double amplitude of 0.037 foot (fig. 9*D*).
	End of chart 2.
14:47:38.7 and 14:49:15.0.	Two aftershocks of magnitudes 6.3 and 6.5, respectively (Pasadena).
15:02:40	P? wave.
15:09:50	S? wave.
15:11	L wave.
15:14	L maximum with period of 13 seconds and double amplitude of 0.04 foot (fig. 9*E*).
20:29:05.9	Aftershock of magnitude 6.6 (Pasadena).
20:50	S? wave.
20:53	L wave.
20:54	L maximum with period of 16 seconds and double amplitude of 0.26 foot (fig. 9*F*).

March 29, 1964

04:46	Small surface wave of unidentified origin with period of 16-seconds and double amplitude of 0.002 foot (fig. 9*G*).
06:04:43.4	Aftershock of magnitude 5.8 (Pasadena).
06:31	L maximum with period of 18 seconds and double amplitude of 0.0068 foot (fig. 9*H*).
22:10	Measured depth to water was 87.07 feet giving a water-level rise of 12.13 feet since pre-earthquake measurement on March 27, 1964.
	End of chart 3.
16:40:59.3	Aftershock of magnitude 5.8 (Pasadena).
17:11–17:20	Distinct wave train with waves of 16-second period and double amplitude of 0.02 foot (fig. 9*I*).

March 30, 1964

02:18:05.6	Aftershock of magnitude 6.6 (Pasadena).
02:20	P? arrival.
02:35½	S? arrival.
02:42–02:56	Surface waves with period of 17 seconds and maximum double amplitude of 0.062 foot (fig. 9*J*).
07:09:34	Aftershock of magnitude 6.2 (Pasadena).
07:35	S? wave.
07:39	Surface waves with 12-second period and maximum double amplitude of 0.048 foot (fig. 9*K*).
13:03:34.7	Aftershock of magnitude 5.3 (Pasadena).
13:30–13:40	Very faint waves with period of 14 seconds and maximum double amplitude of 0.002 foot (fig. 9*L*).
16:09:27.2	Aftershock of magnitude 5.5 (Pasadena).
16:34–16:45	Waves with maximum period of 25 seconds and double amplitude of 0.0022 foot (fig. 9*M*).
	End of chart 4.

GEOGRAPHIC DISTRIBUTION OF HYDROLOGIC EFFECTS

AFRICA

LIBYA

A good record of the Alaska earthquake was made on a recorder in Wādī Labdah near Homes, Libya (Fituri Deghaies, Libyan Ministry of Agriculture, written commun., Feb. 15, 1965). The well (3236–1417–B) is about 4 kilometers from the Mediterranean Sea, has a depth of 77 meters and a diameter of 8 inches. It yields 40 cubic meters per hour. The fluctuation had a double amplitude of 0.24 feet, and the rise was equal to the decline. Three other wells at Bir al Ghanam, Wādī al Magānin, and Qaşr Khiar recorded the quake, but no other details have been furnished (Hadi Ali Tarhuni, Libyan Ministry of Agriculture, written commun., Dec. 25, 1964).

REPUBLIC OF SOUTH AFRICA

About 100 charts from observation-well recorders in the Republic of South Africa were examined, but only three showed a fluctuation caused by the Alaska earthquake (O. R. Van Eeden, Director, Geol. Survey, written commun., Sept. 8, 1965). Two of the wells are on Robben Island (lat 33°49′ S. and long 18°22′ E.). They penetrate Malmesbury Hornfels of Precambrian age and are 135 and 74 feet deep. The Alaska earthquake caused a fluctuation at about 04:00 G.c.t., March 28 of 0.23 foot in the shallower well and 0.20 foot in the deeper well.

The third well, at Fauresmith (lat 29°45′ S. and long 25°20′ E.), penetrates shale and sandstone of the Beaufort Series of the Karroo System (Permian-Triassic in age) and is 130 feet deep, and the depth to water is about 13 feet. The Alaska earthquake caused a fluctuation of 0.60 foot.

SOUTH-WEST AFRICA

The Alaska earthquake was registered in an observation well at Windhoek (Dr. W. L. Van Wyk, Assistant Director, Geol. Survey of South-West Africa, written commun., Aug. 25, 1965). The recorder chart, with a time scale of 12 mm per day and a gage-height ratio of 1:5, had a fluctuation of 0.50 foot at about 05:00 G.c.t. The well is 600 feet deep, in quartzite and mica schist. The water was struck in a fault zone, and the water level is 100 feet below land surface.

UNITED ARAB REPUBLIC (EGYPT)

The Alaska earthquake was recorded in an artesian well in Kharga Oasis in the Western Desert of Egypt. The initial response was a fluctuation with a double amplitude of 0.079 meter (0.24 ft) followed about 1¾ hours later by a fluctuation of 0.030 meter (0.09 ft), and 5 hours after the initial response by a fluctuation of 0.007 meter (0.02 ft). (R. L. Cushman, U.S. AID–USGS engineer, written commun., January 1966.)

ASIA

ISRAEL

The Alaska earthquake was recorded in eight observation wells, of which three were in the mountains and five in the coastal plain of Israel (M. Jacobs, Director, Water Comm. Israel, written commun., May 19, 1965). The double amplitudes of fluctuations ranged from 0.003 to 0.075 meters (0.01–0.25 ft).

REPUBLIC OF THE PHILIPPINES

Hydroseisms from the Alaska earthquake were recorded in 17 of 25 instrumentally equipped wells on the Island of Luzon, Republic of the Philippines. The hydroseisms ranged from 1 to 15 centimeters (0.03–0.46 ft) in double amplitude. (A. B. Delena, Bureau of Public Works, written commun., April 13, 1966.)

AUSTRALIA

In the Northern Territory, two observation well recorders, 16 miles southeast of Darwin, were in operation at the time of the Alaska earthquake and both registered hydroseisms (R. N. Eden, Director of Water Resources, written commun., Aug. 11, 1965). These two are 170 feet apart, are at lat 12°30′35″ S. and long 131°04′50″ E. Well M1, with a depth of 114 feet, had a fluctuation at about 04:00 G.c.t. of 0.10 foot. Well M2, with a depth of 227 feet, had fluctuations of 2.25 feet at 04:20 G.c.t., 0.98 foot at 06:00 G.c.t., and 0.08 foot at 07:20 G.c.t.

A seismic seiche was recorded at gaging station 113A on the Victoria River at lat 16°22′ S. and long 131°06′ E. This station was the only one of a large number in operation in the Northern Territory of Australia that registered any effect of the Alaska earthquake. The seiche had a double amplitude of 0.033 foot and was recorded at 04:20 G.c.t.

A recorder on the Tatangara Reservoir in New South Wales, at lat 35°47′53″ S. and long 148°-39′44″ E., recorded a seiche at 04:20 G.c.t. on March 28, 1964, that also was caused by the Alaska earthquake.

Twelve charts from water-level recorders of the Victoria State Electricity Commission were examined closely for unusual movements on March 28, 1964, by G. Patterson, Engineer for Design and Construction (written commun., Oct. 19, 1965). On only one was there any discernible fluctuation. This gage on the Melicke Munjie River recorded a seismic seiche at about the time of the Alaska earthquake.

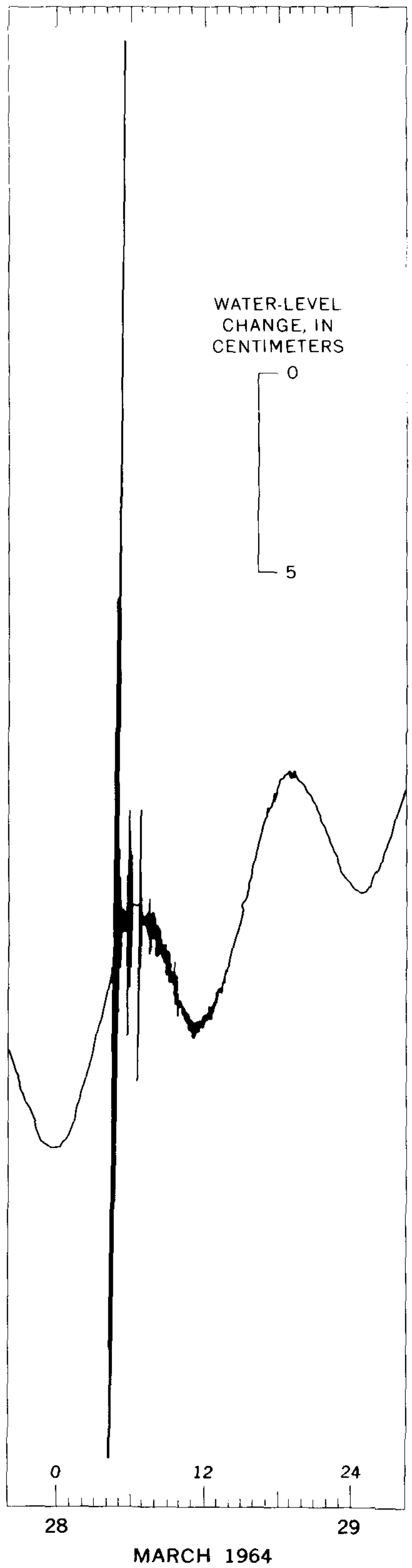
EUROPE

BELGIUM

An extremely interesting and unusual hydroseism was recorded at Heibaart, Belgium (fig. 10). A large fluctuation preceded the maximum one, whereas all the hydroseisms recorded in the United States seemingly showed the maximum fluctuation at the start of the record. Another unusual feature of this hydroseism is that the waves that went the long way around the world (W_2, W_3, . . .) were recorded distinctly. A copy of the hydroseismogram was received from A. Sterling, Director, Hydraulic Research Laboratory, Belgian Ministry of Public Works, and is reproduced as figure 10.

DENMARK

The Alaska earthquake was recorded in 7 of 14 observation wells in Denmark (Andersen, 1965, p. 40). The largest double amplitude was 0.12 meter (0.40 ft) in a well that is 66 meters deep, cased to 62 meters, and 10 inches in diameter. The well produces from limestone in which the casing is seated. The water level in the well at the time of the quake was 14 meters below land surface.



10.—Hydroseism of the Alaska earthquake recorded at Heibaart, Belgium. Greenwich civil time.

UNITED KINGDOM

The effect of the Alaska earthquake was recorded on 34 wells in England (J. Ineson, Chief Geologist, Water Dept., Geol. Survey and Museum, written commun., Feb. 12, 1965). Of these, 25 are in Cretaceous chalk, 7 in Jurassic limestone, 1 in Permo-Triassic sandstone, and 1 in the Lower Greensand. The maximum fluctuation was 1.08 feet in the Lincolnshire Limestone of Jurassic age. The maximum fluctuation in chalk wells was nearly as large, being 1.05 feet. These wells range in depth from 200 to 1,271 feet.

CANADA

ALBERTA

Hydroseisms of the Alaska quake were recorded in 24 of 48 observation wells in Alberta. Fluctuations ranged from greater than 5 feet to less than 0.02 foot. Three records showed a permanent change in water levels after the quake. One of these is interpreted by Gabert (1965) to result from stress induced in the aquifer by the quake and which was dissipated gradually with time. None of the records showed any of the aftershocks even though Alberta is closer to the epicenter than any other geographic area from which hydroseisms were reported.

Thirty seismic seiches from surface-water gages in Alberta were reported (R. H. Clark, Secretary, Canadian Natl. Comm. Internat. Hydrologic Decade, written commun., Sept. 21, 1965). These ranged from 0.01 to 0.32 foot.

BRITISH COLUMBIA

Three observation wells in British Columbia that penetrate unconsolidated Pleistocene clay, till, and sand failed to record any effect of the Alaska quake (E. Carl Halstead, Canada Geol. Survey, written commun., Oct. 30, 1964).

The Alaska earthquake was registered on many surface-water recorders in operation in British Columbia. On most of these the quake was recorded as a small jog on the chart. A total of 13 seismic seiches ranging in size from 0.05 to 1.25 feet are reported from British Columbia by R. H. Clark (written commun., Sept. 21, 1965). In addition, 10 others, of which 7 are illustrated, are given by Wigen and White (1964b, p. 6, figs. 2, 4). A peculiarity in the distribution of the seiches was noted by H. T. Samsden (District Engineer, Canada Dept. of Natural Resource, written commun., Dec. 1, 1964). None of the recorders on Vancouver Island or in the Koanagan River and Lake system in British Columbia registered any effect of the earthquake.

MANITOBA

Wells in the Red River Valley near Winnipeg, Manitoba, showed fluctuations greater than 1 foot. These wells penetrate an artesian aquifer in the Red River Formation of Ordovician age. The aquifer is in fractured carbonate rocks and is confined by till and glacial-lake clay (Scott and Render, 1965, p. 264).

In a tabulation of seiches in Canada (R. H. Clark, written commun., Sept. 21, 1965), seven are listed from surface-water gages in Manitoba. The largest fluctuation, 0.39 foot, was at a gage on Nelson River; the smallest, 0.03 foot, was at a gage on Lake Manitoba.

NORTHWEST TERRITORIES

Wigen and White (1964b, p. 6) list a seiche of 0.30 foot at Cambridge Bay. R. H. Clark (written commun., Sept. 21, 1965) lists four other seiches in the Northwest Territories: Talston River (0.15 ft), Willowlake River (0.03 ft), Great Bear Lake (0.22 ft), and Lockhart River (0.08 ft).

ONTARIO

Three out of 20 instrumentally equipped wells of the Ontario Water Resources Commission recorded hydroseisms of the Alaska earthquake (B. A. Singh, Division of Water Resources, written commun., Jan. 3, 1966). Near Toronto, two wells in a gravel aquifer recorded hydroseisms with double amplitudes of 0.14 and 0.08 foot. The third, a well in a sand and gravel aquifer in the County of Perth, recorded a double amplitude of 0.08 foot.

A well record in the Ottawa area also showed the Alaska earthquake. This well, which penetrates an unconfined aquifer, showed an initial increase of 0.20 foot in water level followed by a decline of 1.1 feet and a recovery to the original level after several days (Scott and Render, 1965, p. 267).

Four small seismic seiches at stream gages in Ontario are reported by R. H. Clark (written commun., Sept. 21, 1965): Gull River (0.03 ft), Skootamata River (0.04 ft), Mississagi River (0.07 ft), and French River (0.03 ft).

SASKATCHEWAN

R. H. Clark (written commun., Sept. 21, 1965) reported five seismic seiches from surface-water gages in Saskatchewan: Buffalo Pound (0.06 ft), Fond-du-Lac River (0.07 ft), Weyburn Reservoir (0.05 ft), Deloraine Reservoir (0.45 ft), and Long Creek (0.32 ft).

A farmer in Saskatchewan reports that on the day following the Alaska earthquake his well water had a distinctive purple color. Believing that the ejector was responsible for the discoloration, he opened the well and pulled the casing to check on the ejector. The farm well is 6 inches in diameter, 111 feet deep, and had the ejector set at 90 feet. The static level normally was 44 feet but when the well was opened the level was at 69 feet, about 25 feet lower than normal. Prior to the Alaska quake, the purple coloration had never appeared. When sampled on April 24, 1964, the well water still had a purple color. The purple color faded gradually and by midsummer had disappeared. (W. Nemanishen, Saskatchewan Dept. of Agriculture, written commun., June 4, 1965).

UNITED STATES

Hydroseismic effects were reported virtually throughout the United States, although New England and the States east of the Appalachians did not register many hydroseisms. New Jersey, however, reported 40 hydroseisms in wells but only 1 from surface-water gages. Vermont reported none from a well but two from gages. Hydroseisms were most numerous and of largest size in the southeastern States, the ones, surprisingly, that are most distant from the epicenter.

Hydroseisms in the United States are listed by State in table 3, and are broken down into ground-water observation wells and surface-water gages. Listed also are the maximum well and gage fluctuations recorded in each State.

Data on individual hydroseisms in wells caused by the Alaska earthquake are given in table 7 (p. C39).

ALABAMA

Hydroseisms from the Alaska earthquake were recorded in 20 observation wells scattered through-

TABLE 3.—*Number and maximum hydroseisms recorded in the United States from the Alaska earthquake of March 27, 1964*

	Observation wells		Surface-water gages	
	Number recorded	Maximum double amplitude (feet)	Number recorded	Maximum double amplitude (feet)
Alabama	20	>10	27	0.22
Alaska	3	>24(?)	32	1.53
Arizona	12	1.1	9	.35
Arkansas	5	3.3	41	1.45
California	42	2.4	27	.42
Colorado	1	.3	14	.30
Connecticut	0	----------	0	----------
Delaware	No report	----------	No report	----------
Florida	92	17	93	.66
Georgia	24	>10	26	.22
Hawaii	18	4.6	5	.17
Idaho	24	>5	5	.56
Illinois	21	>10	8	.10
Indiana	22	8.2	16	.39
Iowa	13	4.7	3	.02
Kansas	1	.4	12	.34
Kentucky	20	1.8	4	.57
Louisiana	37	>5	69	.68
Maine	1	.2	0	----------
Maryland	4	.3	3	.04
Massachusetts	1	.6	0	----------
Michigan	48	>5	16	1.83
Minnesota	15	4.4	1	.03
Mississippi	11	2.3	22	.90
Missouri	31	>10	18	.87
Montana	3	2.9	16	.10
Nebraska	9	4.1	14	.18
Nevada	5	1.7	0	----------
New Hampshire	0	----------	1	Trace
New Jersey	40	4.4	1(?)	.08(?)
New Mexico	12	>5	27	.26
New York	9	2.1	4	Trace
North Carolina	3	1.8	1	.05
North Dakota	3	1.9	3	.06
Ohio	32	5.8	25	.25
Oklahoma	6	>1	37	.44
Oregon	1	.055	8	.14
Pennsylvania	19	2.2	2	.05
Puerto Rico	4	3.4	0	----------
Rhode Island	0	----------	0	----------
South Carolina	8	9.0	8	.12
South Dakota	4	23	6	.14
Tennessee	21	3.9	32	.42
Texas	28	>5.8	70	.67
Utah	14	3.1	8	.06
Vermont	0	----------	2	.23
Virgin Islands	1	.05	0	----------
Virginia	1	1.6	0	----------
Washington	7	3.9	21	1.04
West Virginia	1	.3	0	----------
Wisconsin	17	3.5	6	.02
Wyoming	2	2.0	12	.08
Total	716	----------	755	----------

out the Valley and Ridge, Piedmont, and Coastal Plain provinces of the State. A water-level fluctuation of more than 10 feet in one well in Jefferson County (Jef-1) that is equipped with 1:10 gage-scale gears was indicated by the fact that the drum made more than one rotation. Drums in three other wells equipped with 1:2 and 1:1 gears also made complete rotations. In a well in Lawrence County (Law-2), the water motion was so severe that it caused the beaded cable to jump off the grooved pulley of the drum.

Seismic seiches were recorded at 25 gaging stations on rivers in Alabama. The maximum double amplitude of 0.22 foot was recorded at Buttahatchee River below Hamilton, Ala. A double amplitude of 0.18 foot was recorded at two gaging stations, one on the Tennessee River at Triana, the other on Locust Fork at Sayre.

ALASKA

For hydrologic effects in Alaska, see Waller (1966a, b).

ARIZONA

Water levels in wells in several areas in Arizona fluctuated as a result of the Alaska earthquake. The water level in a well in Avra Valley near Tucson, on the fringe of a highly developed agricultural area where large amounts of ground water are withdrawn for irrigation, fluctuated about 8 inches, and lesser fluctuations continued for several hours after the initial shock. The water level in another well near Phoenix fluctuated about 6 inches as a result of the earthquake. Other measurable changes in water level occurred near Bowie where ground water is under artesian pressure. Hydroseisms were recorded in 10 wells in the Colorado River valley. The largest hydroseisms were in two of these wells; fluctuations exceeded 1 foot, but only one well recorded any aftershocks.

The largest seiche in the State was recorded at Coolidge Dam on the San Carlos Reservoir. The maximum double amplitude was 0.35 foot, and fluctuations continued for nearly 2 hours. Seiches were recorded at five other gages, a minor drop in stage was recorded for the earthquake at two other gages, and a slight trace was recorded at another.

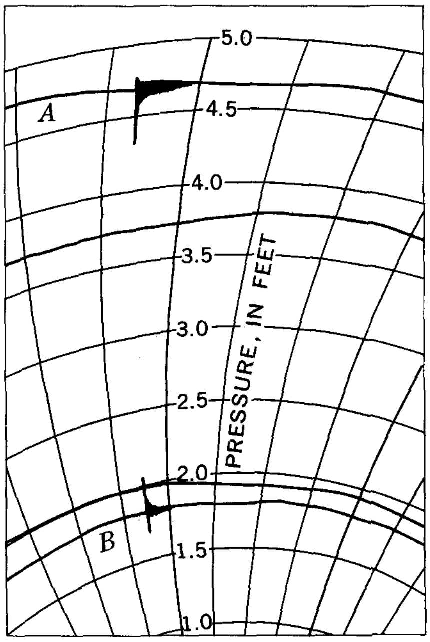
ARKANSAS

The hydroseisms reported from five wells in Arkansas were all rather large: Two that rotated the recorder drum showed movement in excess of 1 foot; the other three ranged from 1.49 to 3.30 feet in double amplitude. Even though the hydroseisms are large, none of the wells recorded any aftershocks.

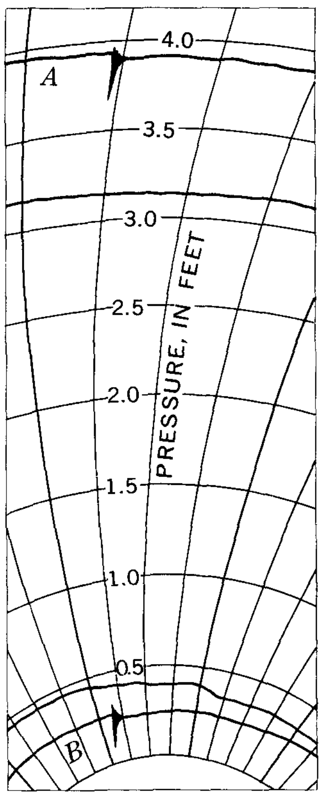
Nearly all the 41 hydroseisms from surface gages in Arkansas were recorded as seiches. The largest was 1.45 feet on Lake Ouachita near Hot Springs (fig. 2*A*). The record from Piney Creek near Dover seems to show a second seiche recorded an hour later than the main shock. The amplitudes were 0.24 foot for the first seiche and 0.03 foot for the second. The gage on South Fork of Ouachita River near Mount Ida recorded a seiche of 0.11 foot followed by a drop in stage of 0.015 foot. At Six Mile Creek subwatershed near Chismville, the earthquake was recorded as a brief 0.03-foot decline in stage.

CALIFORNIA

The hydroseisms recorded in California were rather uniformly small. The maximum reported was 2.39 feet, and only 3 wells out of 42 had movement greater than 1 foot; however, some of the records are unusual. Two adjacent piezometers, 7E2 and 7E4, in T. 6 S., R. 10 W., Orange County, recorded hydroseisms, one from an aquifer (fig. 11A) at 90–120 feet, the other from an aquifer (fig. 11B) at 300–330 feet. The contrast between these two records is interesting because the upper aquifer registered a rise of only 0.03 foot but a fall of 0.17 foot. In the lower aquifer the relative movement was the reverse—a rise of 0.11 foot and a fall of 0.06 foot.



11.—Two dissimilar hydroseisms recorded from two aquifers tapped by adjacent piezometers in Orange County, Calif.



12.—Two similar hydroseisms recorded from two aquifers tapped by adjacent piezometers in Orange County, Calif.

In two other similarly adjacent piezometers, 1Q4 and 1Q6, in T. 6 S., R. 11 W., the hydroseisms recorded almost identically in both the upper aquifer (fig. 12A) at 70–170 feet and the lower one (fig. 12B) at 300–360 feet. These two wells are the only ones known to the author in which hydroseisms from the same quake have been recorded for two different aquifers. The second deepest well known from which a hydroseism has been recorded is in Fresno County (well 19S/17E–35N1). It is 2,030 feet deep (measured depth, 1,955 ft), and the casing is perforated from 608 feet to bottom.

In California, 27 hydroseisms were recorded at gaging stations. On the chart from Lower Twin Lake near Bridgeport, the seiche was recorded during a 4-hour period. The gage at Lake Success near Success, Calif., registered a 0.02-foot rise over about a 10-minute period at the time when the quake was recorded at the other gages in the State.

The gage on LaFayette Reservoir east of Berkeley showed fluctuations above the normal water level but none below. The earthquake-induced, water-level movement continued for possibly as long as 4 hours, but the maximum rise was only 0.02 foot. The Yuba River at Englebright Dam recorded a seiche that seemingly lasted about 8 hours. The gage at Merced River diversion showed a 0.01-foot permanent drop in water level at the time of the earthquake. The largest seiche, of 0.42 foot, was recorded on the gage at Chabot Reservoir, and fluctuations died down in about 3 hours.

COLORADO

Three recorders were in operation in Colorado wells, but only one recorded a hydroseism. It is on the flood plain of the Arkansas River in southeastern Colorado.

The distribution of hydroseisms at Colorado gaging stations was unusual. Fourteen were recorded on the western slope of Colorado, but not one was recorded in the entire eastern half of the State. About 40 stations were out of operation due to ice conditions at the time of the quake. No doubt some of these stations would have recorded the earthquake if they had been operating. The largest seiche of 0.30 foot recorded at White River near Meeker was unusual; for so large a fluctuation, there was no coda portion. The water level returned instantaneously to normal level.

CONNECTICUT

Neither wells nor stream gages in Connecticut recorded the earthquake.

DELAWARE

No report received from Delaware.

FLORIDA

The Alaska earthquake gave Florida two distinctions. Even though it is the State farthest from the epicenter, more wells and more streams in Florida recorded the earthquake than in any other State. It furnished 92 well records compared with 48 from Michigan, which had the second largest number. Likewise, the fluctuation of 17 feet in a well (Taylor 35) at Perry, Fla., is the second largest recorded fluctuation for any well outside Alaska and is the largest reported fluctuation in an open-hole well. The earthquake evidently caused violent water movement in some wells, especially in the Tampa area, for there one recorded pen was dislodged, and at six wells the beaded cable was thrown off the recorder pulley. Of the 92 wells in which the earthquake was recorded, 49 had fluctuations with a double amplitude greater than 1 foot. Aftershocks were recorded in only one well, that at Perry, Fla.

A few wells in Florida were residually affected by the earthquake. A well in Clay County on the crest of a water-table high recorded a "normal" hydroseism of large size, but immediately afterward the water level began a slow decline (fig. 13). This decline continued for several weeks until the water level finally stabilized about 4 feet below the preearthquake level. This prolonged decline may indicate that the earthquake caused water-table highs to be lowered slightly by somehow facilitating drainage. Water levels in other wells seemed to show a change in trend coincident in time with the earthquake. A well in Hardee County (731–145–1) showed a sudden drop of 0.4 foot coincident with the initial phase of the earthquake, and a "coda" portion then registered at the lower level. From the chart it would appear that the drop in level must have some physical significance.

Practically every surface-water gage in Florida recorded the Alaska earthquake. The records were so numerous that copies of only the 93 best records were submitted. The maximum hydroseism at a gage was 0.66 foot.

The gages on some tidal streams and canals of coastal Florida are equipped to record both stage and deflections of velocity vanes. From the record of the deflections, the changes in velocity and in direction of flow can be calculated. Two examples of such records are shown in figure 14. The records of these gages promise some interesting interpretations if studied further.

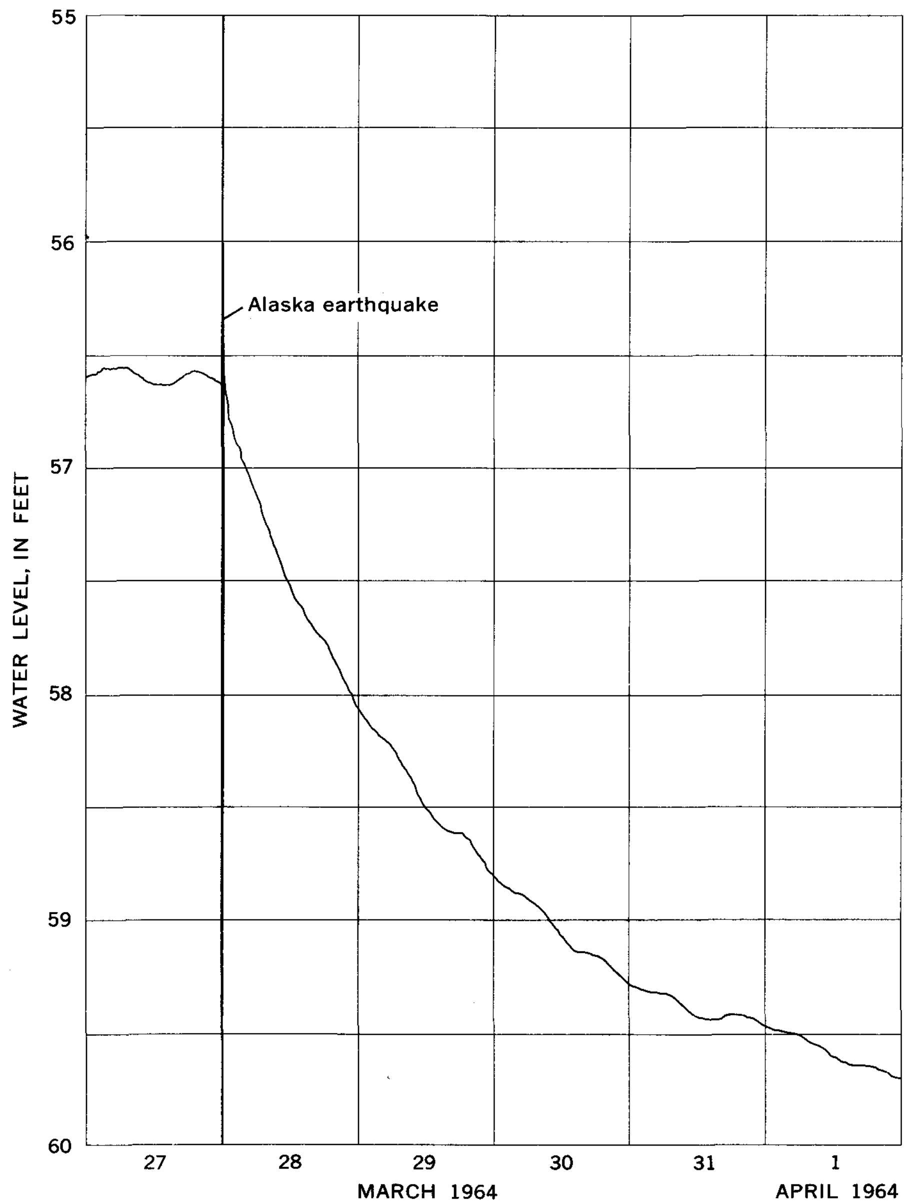
GEORGIA

The hydroseism recorded in a Piedmont well at the Georgia Nuclear Laboratory, Dawson County, enabled the author to score a scientific "first." Upon examining the recorder chart on the day after the earthquake he realized from study of previous hydroseisms from this well that the earthquake was of great magnitude. He telephoned his findings to the Atlanta Journal-Constitution, and the Sunday paper reported that the quake was greater than an 8.3 magnitude and "may be bigger than any quake yet recorded instrumentally." This is the first and only instance known where a hydroseism has provided an estimate of earthquake magnitude as quickly as one furnished by seismologists.

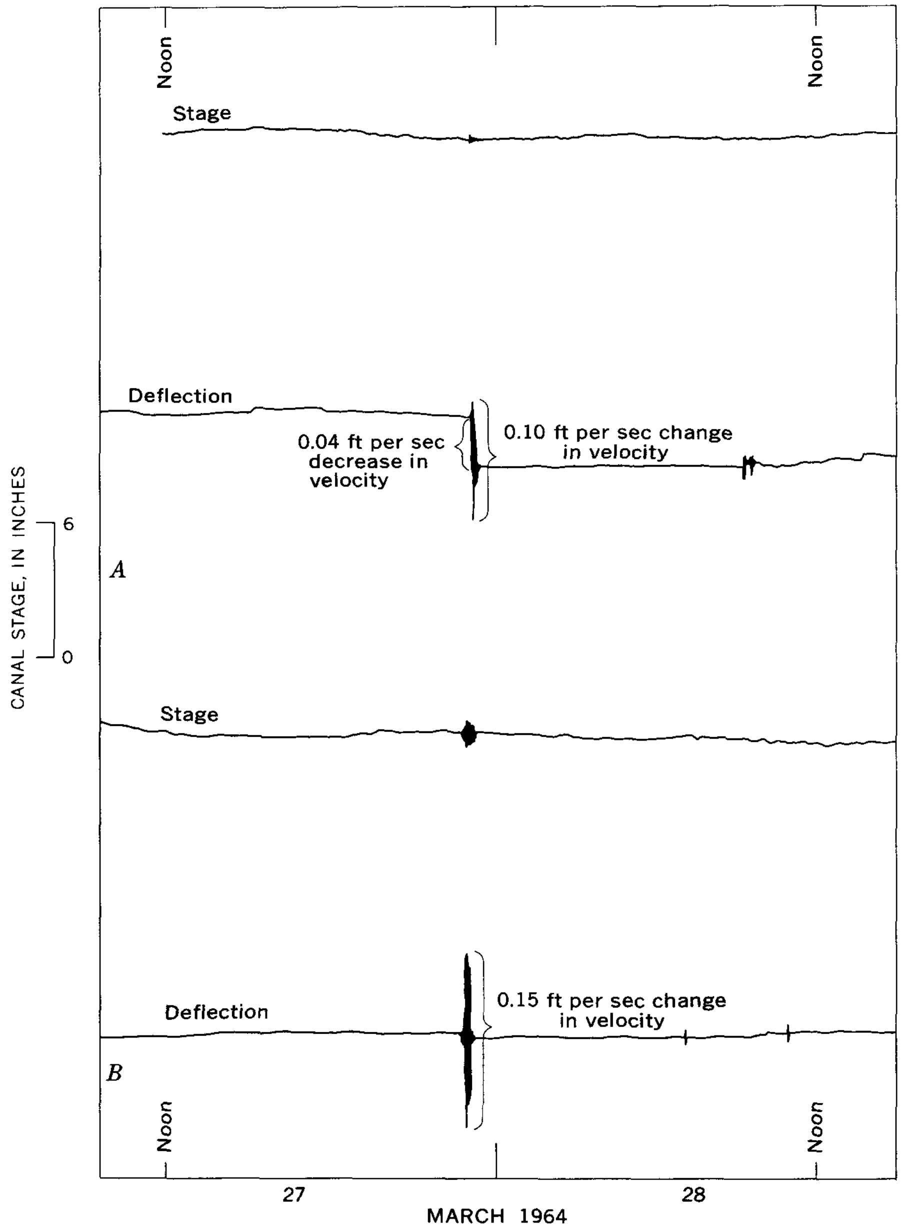
Of the 24 hydroseisms recorded in Georgia wells, 20 were larger than 1 foot. Seismic seiches were also recorded at 26 gaging stations scattered throughout the Valley and Ridge, Piedmont, and Coastal Plain Provinces (fig. 15). Most of these stations are on fairly deeply entrenched streams. The maximum double amplitude was 0.18 foot.

No seiches were recorded or reported from Brunswick or Savannah on the Atlantic coast. This absence was unexpected because seiches were so large and numerous on the gulf coast.

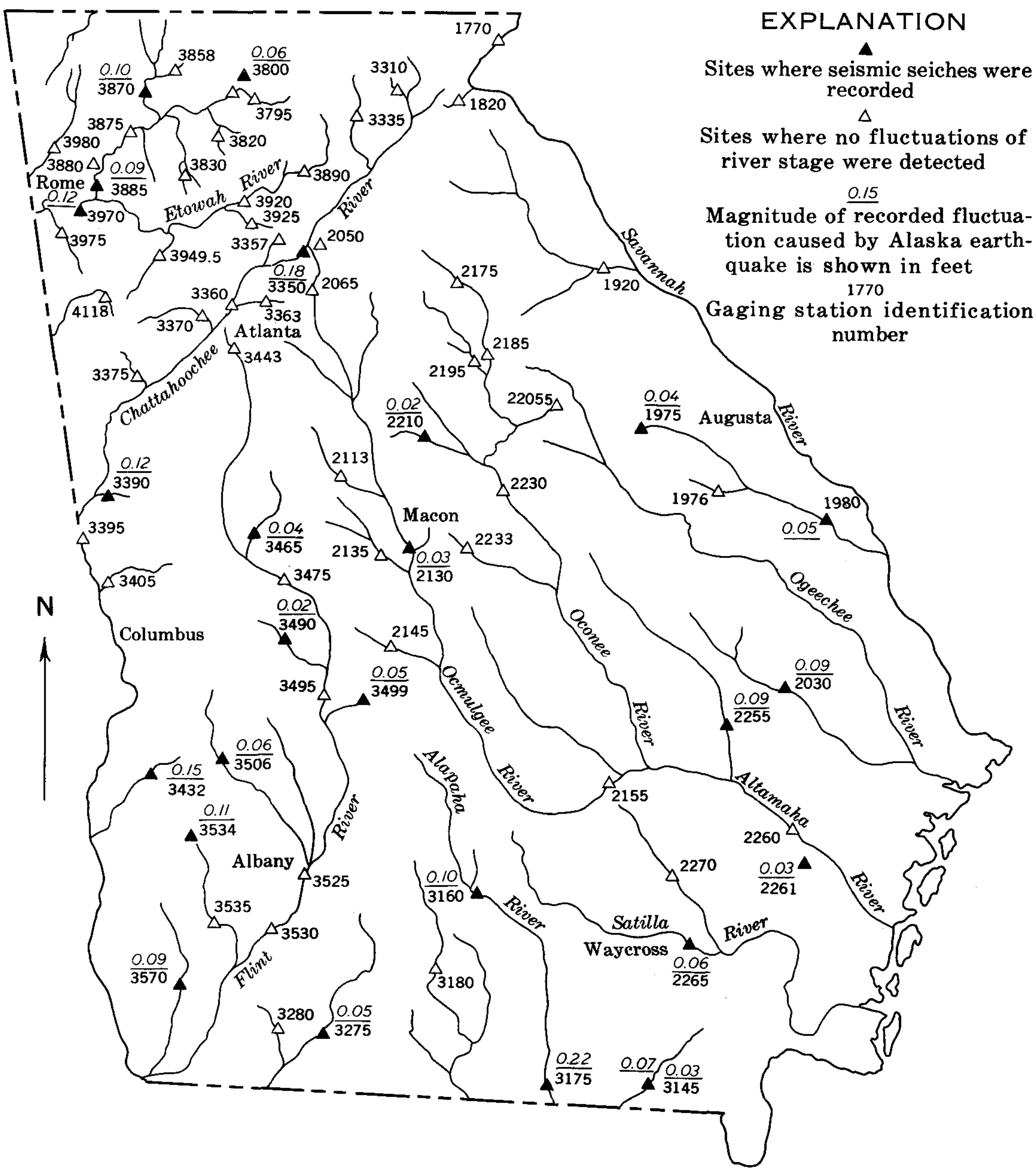
At Brunswick, the water levels began to rise in all the wells immediately after the quake, and a slow steady rise continued for about 15 days. The measured rise was 3.3 feet in well E–143, 2.9 feet in well J–35, 3.0 feet in well J–36, and 2.6 feet in well J–67. The water level in well J–67 continued to rise after the others leveled off. Residents of the area reported that after the earthquake their wells yielded water containing black sooty material. The earthquake seemingly produced a surge so violent that it loosened black iron sulfide that had gradually coated well casings,



13.—Part of a 4-foot decline caused by the Alaska earthquake in water level in a well in Clay County, Fla. Eastern standard time.



14.—Alaska earthquake shown on stage and deflection records. *A*, Biscayne canal near Miami, Fla. *B*, Snake Creek Canal at North Miami Beach, Fla. Eastern standard time.



15.—Map of Georgia showing locations of gaging stations and size of seiches recorded from the Alaska earthquake.

pipes, and iron fixtures of water systems. Others reported that former flowing wells began again to flow. Most of these were old wells that had been drilled to a water-bearing unit of sand and calcareous sand that lies above the principal artesian aquifer. These old wells are from 450 to 500 feet deep and obtain water from sand at depths of 350–450 feet.

The rise in ground-water level due to the earthquake was seemingly a permanent change in the Brunswick area. When piezometric maps for the end of 1962 and 1964 were drawn and compared, the seismic boost in water level made the two maps look similar despite increased consumption that normally would have caused a decline in regional water levels.

The spring flow used as a public supply at Cave Spring and water from the city supply wells at Cedartown became turbid at the time of the earthquake and remained so for several days. The earthquake coincided with extremely heavy rainfall, so it is not certain whether one or the other or both were the cause of this temporary deterioration in water quality.

HAWAII

Sixteen hydroseisms reported from wells in Hawaii had recorded double amplitudes ranging from 0.05 to 1.85 feet. A comparison of seven of these with the tidal efficiencies of the wells suggests that tidal efficiency of a well has no relation to the amplitude of a hydroseism.

The largest fluctuation in Hawaii was not recorded in a well but in a horizontal tunnel 1,614 feet long. The tunnel, driven into a mountain for water, has the innermost 24 feet shut off by a 10-foot bulkhead that holds water at 160–180 feet of pressure. At the time of the Alaska earthquake the water was discharging and pressure was only 126 feet, or 55 p.s.i. (pounds per square inch). It was this pressure that fluctuated 4.60 feet owing to the earthquake.

Five seiches were recorded at gages on the Islands of Kauai and of Hawaii, the largest having a double amplitude of 0.17 foot. The others were all small and hardly noticeable on the charts. No seiches were recorded at gaging stations on the Islands of Oahu, Maui, or Molokai.

IDAHO

A total of 24 hydroseisms was reported from Idaho. The most outstanding is from a well in Latah County where the double amplitude was more than 5 feet and where nine aftershocks were registered. No other well in the State is known to have recorded more than one of the aftershocks.

The largest seiche reported from Idaho was recorded in a pond in Butte County (fig. 3). The depth of water in the pond at the time was 14.10 feet. The maximum double amplitude was 0.56 foot, and the fluctuations continued for about 2 hours and diminished slowly to a static level. The pond bottom is in alluvial sand and gravel of Big Lost River. Only four other seiches were reported from gages in Idaho. These were 0.04 foot or less in size and were all in the Idaho Falls area.

The earthquake worsened the pumping problem at the Clayton Silver Mines in Custer County, Idaho. After the earthquake the flow of water in the mine increased from 750 to 1,150 gallons per minute.

ILLINOIS

A total of 28 hydroseisms was reported from Illinois wells. Only two aftershocks were recorded, and both were registered in well DuPage ANL–10.

Seismic seiches were recorded in Illinois at two lake stations: Wolf Lake at Chicago and Money Creek at Lake Bloomington. These seiches were both recorded at 10:00 p.m. c.s.t. on March 27, 1964, and had a double amplitude of 0.08 foot at the former and 0.05 foot at the latter. The Illinois Water Survey reports that two river gages, one on the West Branch, the other on the East Branch of DuPage River, recorded seiches from the Alaska earthquake. The fluctuations were 0.04 foot and 0.03 foot, respectively.

A well in Cook County (37N 14E–22.1b), which taps a Cambro-Ordovician sandstone and has a depth of 1,648 feet, reportedly pumped sand following the quake. Two wells in Union County reportedly yielded muddy water after the quake.

INDIANA

Twenty-one hydroseisms having double amplitudes ranging from 0.08 to 8.25 feet were reported from Indiana wells. Well Marion Ma–32 was exceptional in that it recorded 12 aftershocks, one of the most complete records in any well in the United States. This well is equipped with a recorder operating with 1:1 vertical gears, so the Alaska earthquake itself was shown only as greater than 1 foot, but oscillations of this amount or more continued throughout at least a 2-hour period.

Seismic seiches were recorded at 16 stations in Indiana. Of these, the maximum fluctuation was 0.39 foot at an auxiliary gage on the White River near Nora where fluctuations were recorded over a period of 55 minutes. Four of the seiches were on lakes and one was on a reservoir.

IOWA—ALASKA EARTHQUAKE EFFECTS ON GROUND WATER

By R. W. Coble

The Alaska earthquake caused the water levels to fluctuate in many wells in Iowa. The earthquake occurred at 9:36 p.m. c.s.t.,

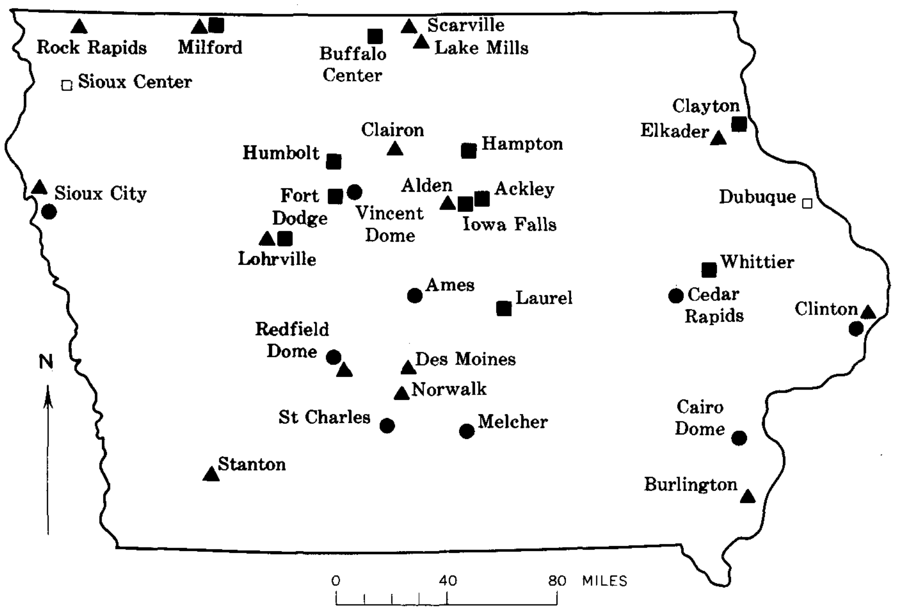
229-356 O—66——4

and the L wave arrived in Iowa about 9:50 p.m. The L wave was calculated to have arrived at Loras College Seismograph Station, Dubuque, Iowa, at 9:52 p.m., c.s.t., or 03:52 G.c.t. (Dr. William Stauder, St. Louis Univ., written commun., Feb. 26, 1965). The timing mechanisms on the water-level recorders on wells in Iowa are not precise enough to determine the exact minute that the earthquake affected the aquifers in the State, but there were many indications that something happened just before 10 p.m.

Aquifers in Iowa responded to the earthquake waves as shown by (1) the seismic fluctuations on some recorder charts; (2) turbid water in some wells and springs, probably caused by the disturbance and movement of silt, clay, and colloidal particles within the aquifers; and (3) in some wells a permanent change, either a rise or fall, of the water level. These effects are summarized in figure 16 and in table 4.

At Redfield Dome, the water levels in several different aquifers showed various types and amounts of seismic fluctuations as is shown in figure 17. In this same area, two of the four observation wells drilled to the St. Peter Sandstone of Ordovician age showed a seismic fluctuation; the other two showed no effect. Why some wells are affected and others are not is yet to be determined.

The best record of a seismic fluctuation is shown on a recorder chart from an observation well in the Franconia Sandstone of Cambrian age at Vincent Dome (fig. 18). A seismic fluctuation of 0.23 foot occurred just before 10 p.m. A series of smaller fluctuations were recorded after the main one. Many of these can be matched with some aftershocks; however, many aftershocks were not recorded.

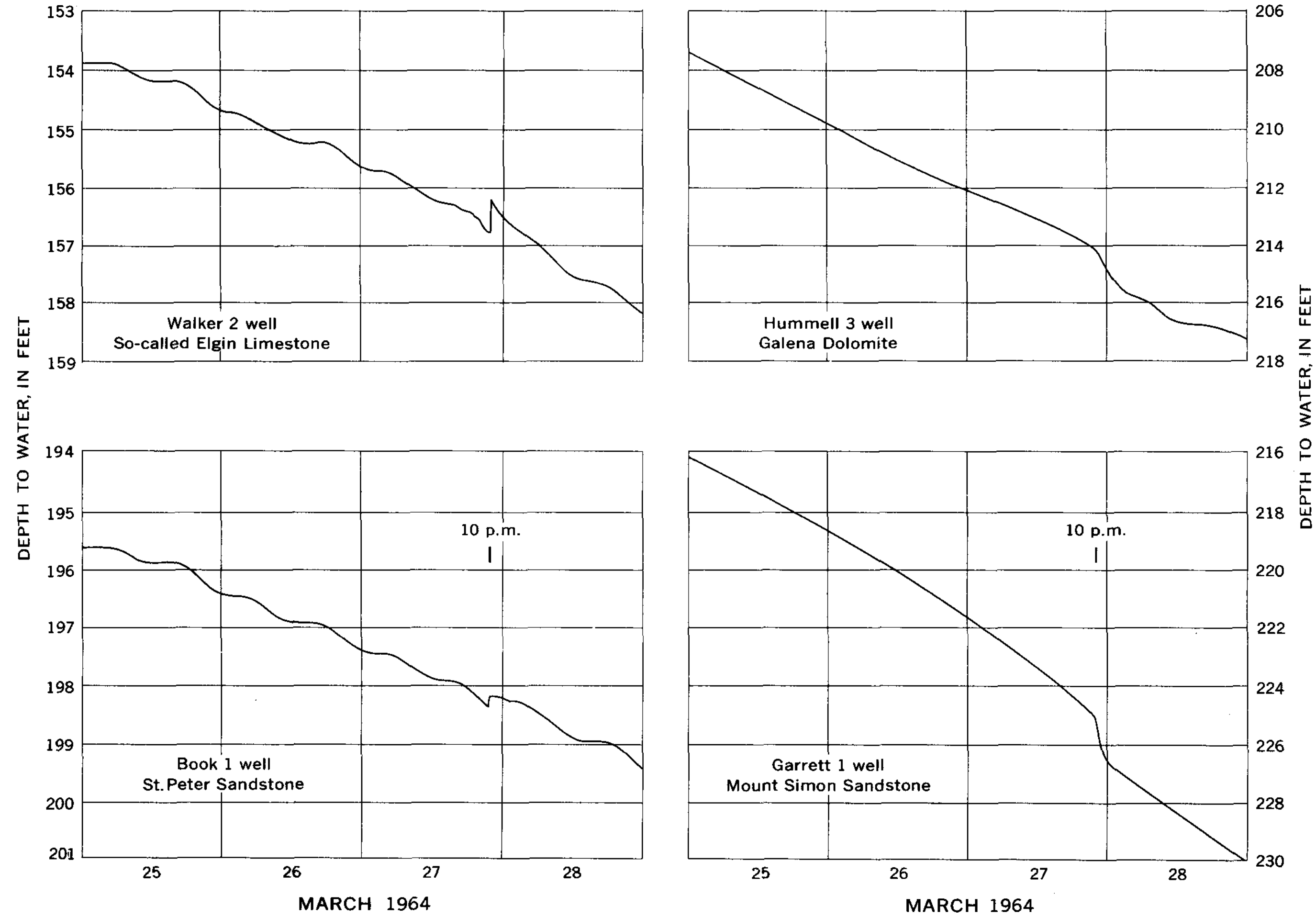


16.—Location of reported ground-water disturbances in Iowa caused by the Alaska earthquake. •, seismic fluctuation; ▲, permanent change; ■, turbid water.

TABLE 4.—*Summary of ground-water disturbances in Iowa caused by the Alaska earthquake*

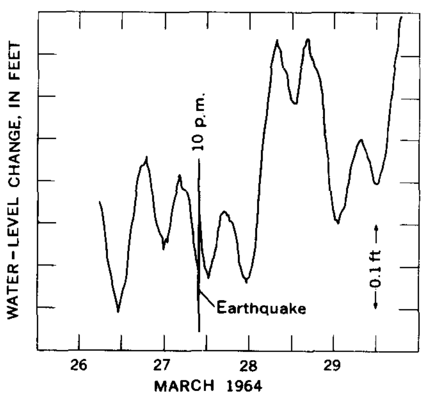
Locality	Aquifer		Effect		
	System	Lithology	Seismic fluctuation (ft)	Turbid water	Water-level change lasting more than 1 week
Ackley				×	
Alden					Lowered.
Ames	Quaternary	Sand and gravel	0.15		
Buffalo Center				×	
Burlington	Mississippian and Devonian.	Carbonate			Lowered 2 ft.
	Ordovician	Sandstone			Lowered 1.8 ft.
Cairo Dome [1]	Silurian	Carbonate	1.2		
	Ordovician	do	4.7(+?)		
Cedar Rapids	Silurian	do	.4		
Clarion					Raised.
Clayton				×	
Clinton	Cambrian and Ordovician.	Sandstone	(2)		Raised 15 ft.[3]
Des Moines	do	do			Raised 18 ft.[3]
Elkader	do	do			Raised 40–50 ft.[3]
Fort Dodge				×	
Hampton				×	
Humboldt	Mississippian	Carbonate		×	
Iowa Falls				×	
Lake Mills					Several reported lowered. Several reported raised.
Laurel	Mississippian	Carbonate		×	
Lohrville	do	do		×	Lowered 10 ft.[3]
Melcher	Quarternary	Sand and gravel	.05		
Milford				×	Lowered.
Norwalk					Raised.
Redfield Dome [4]	Ordovician	Carbonate	.5		
	do	do			Lowered 1 ft.
	do	Sandstone	1.25		
	do	do	.25		
	Cambrian	do			Do.
Rock Rapids	Cretaceous	do			Raised 8 ft.[3]
St. Charles	Mississippian	Carbonate	1.1		
Scarville	Quaternary	Sand and gravel			Lowered 5 or 6 ft.
Sioux City	Cretaceous	Sandstone	[2] 2.5+		Raised 5 ft.[3]
Stanton					Lowered 30 ft in 2 days. Raised 40 ft after 7 days.
Vincent Dome [4]	Cambrian	Sandstone	.23		
Whittier	Silurian	Carbonate		×	

[1] Data from Natural Gas Pipeline Co. of America.
[2] Pumping rate fluctuated.
[3] Known to have lasted more than 7 months.
[4] Data from Northern Natural Gas Co.



17.—**Water-level fluctuations at Redfield Dome, Iowa. Central standard time.**

The seismic fluctuation was so rapid in observation wells drilled to the Dakota Sandstone of Cretaceous age at Sioux City and the Ordovician dolomite at Cairo



18.—**Seismic fluctuations in the Peterson 1 well at Vincent Dome, Iowa. Central standard time.**

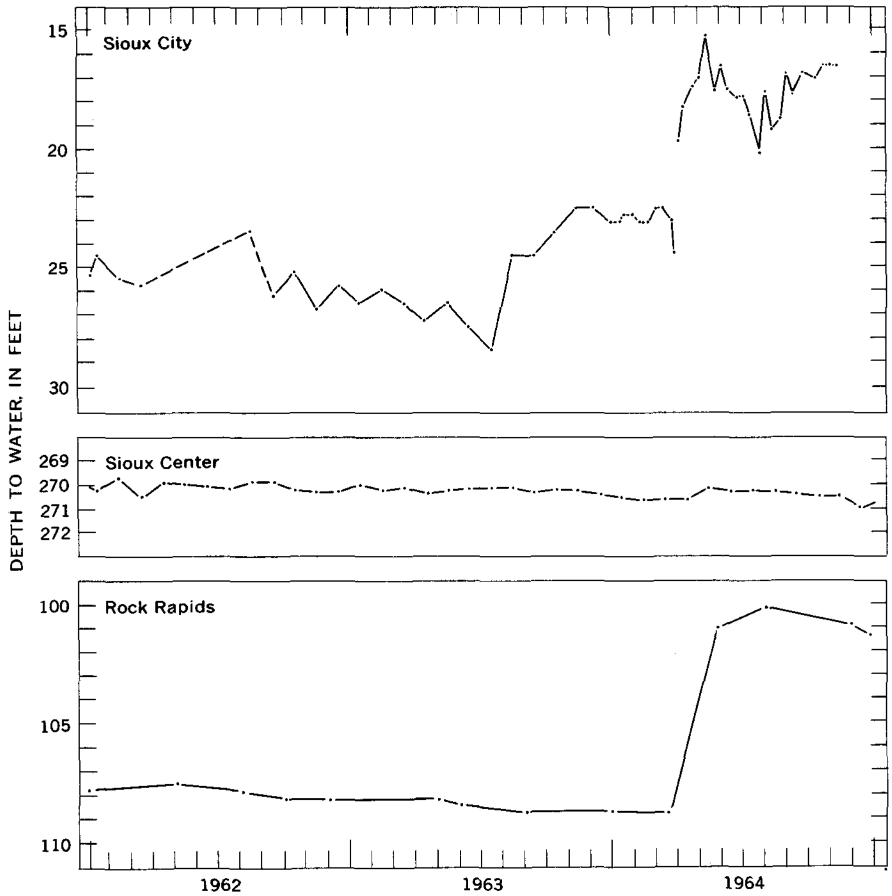
Dome that the recorder pens became disengaged from the float-pulley mechanisms. At Sioux City, the water-plant operator could feel air moving in and out of the well casing as the water level fell and rose. He noted that this "sucking and blowing" of air, which gradually increased in intensity and then slowly diminished, lasted from 5 to 10 minutes.

Several wells produced turbid water after the earthquake. The water generally became clear after a few hours or a few days of normal pumping. Similarly, water from several springs, the water supply for Humboldt, also became turbid. These springs, on the bank of the West Fork of the Des Moines River, flow from limestone of Mississippian age. This water had always contained less than 5 ppm (parts per million) of suspended matter. On the morning of March 28, the turbidity ranged from 70 to 80 ppm. Nearby, water from several small springs that discharge through the river bed was observed to be red, brown, or blackish brown. The turbidity diminished on March 30, but increased again after a few rainy days during the first part of April. It did not completely disappear for another 2½ weeks.

In several localities the ground-water levels seem to have been permanently changed. At Sioux City, the water level in an observation well, tapping the Dakota Sandstone, rose 6 feet and remained high for at least the rest of the year (fig. 19). At Rock Rapids, 75 miles north of Sioux City, the water level in another well drilled to the Dakota Sandstone rose 8 feet. A third well, bottoming in the same aquifer at Sioux Center, which is almost midway between Sioux City and Rock Rapids, showed no seismic fluctuation or permanent change whatsoever.

Limestone of Mississippian age yields water to the municipal well at Lohrville. The nonpumping water level had been 97–98 feet below the land surface for more than 1 year before the earthquake (fig. 20). On March 28, the water level had dropped 3 feet, and after 1½ months the total drop was 10 feet below the original level. This diminished level persisted through the rest of the year.

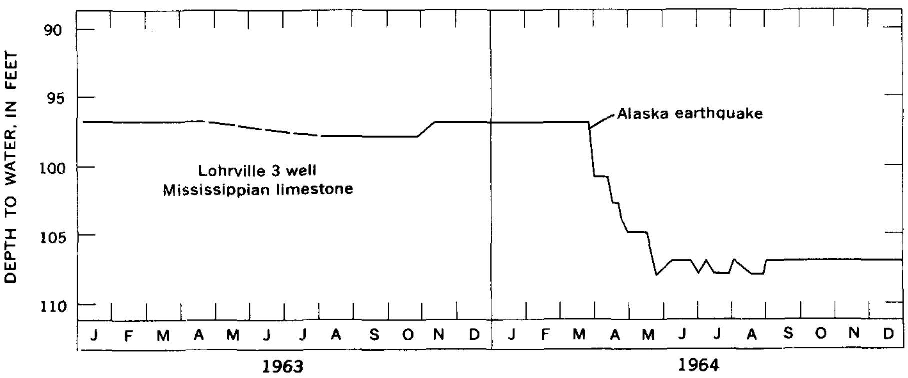
The water level in a well in the Jordan (Cambrian) and St. Peter (Ordovician) Sandstones at the Ford Motor Co. plant in Des Moines rose 18 feet (from 101 to 83 ft) after the earthquake. The level was still high in June 1965. The town of Elkader has several wells that produce water from the Jordan-St. Peter interval. Shock waves from the Alaska earthquake affected all of them in the same manner—the water level rose 40–50 feet and has remained high (fig. 21). In the city of Clinton, adequate records are available for two of the wells which produce water from the Cambrian and Ordovician interval (Mount Simon Sandstone and several overlying sandstone formations through the Prairie du Chien Group). Immediately following the initial shock, the water level rose more than 20 feet in city well 7 (fig. 21). Seismic fluctuation was inferred in city wells 3 and 7 in that the pumping-rate recorders show a total fluctuation of more than 1



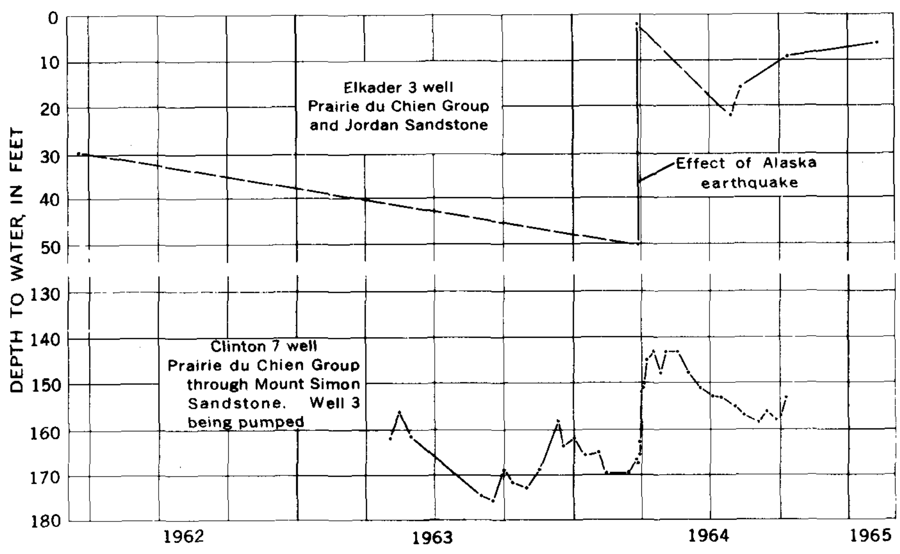
19.—Water levels in the Dakota Sandstone in northwest Iowa.

percent just at 9:55 p.m. c.s.t. (03:55 G.c.t.).

A permanent change in water levels implies a change in the physical properties of the aquifers. A logical assumption is that the porosity and thickness of the aquifers have decreased where the water levels rose and increased where they fell. This change need not be large, even where the level increased as much as 50 feet as at Elkader. Such a change would require only a change of 22 psi in the hydrostatic pressure in the aquifer. Considering only the Jordan Sandstone, which is 100 feet thick near Elkader, and assuming that it has a porosity of 15 percent, the compression of the



20.—Water levels in the city well at Lohrville, Iowa.



21.—Water levels in wells at Elkader and Clinton, Iowa.

water would have to be only about 1.5×10^{-5} feet to raise the pressure 20 psi. This amount of compression would decrease the thickness of the aquifer from 100.000000 feet to 99.999985 feet and the porosity from 15.000000 percent to 14.999985 percent. These computations take into account only the compression of the water. If the sandstone itself were compressed, as it probably would be, the thickness of the aquifer would be decreased somewhat more than 1.5×10^{-5} feet. This decrease in porosity is extremely small and can be considered insignificant with respect to the productivity of the aquifers.

The earthquake was recorded at two surface-water gages in Iowa. Shell Rock River at Northwood declined 0.02 foot in stage between 03:00 and 04:00 G.c.t. on March 28. The stage was steady then until 05:30 G.c.t. and rose 0.01 foot by 06:00 G.c.t. (midnight). A seiche of 0.02 foot was recorded on Lake Ahquabi.

KANSAS

In Kansas, in only 1 out of 12 observation wells is a hydroseism from the Alaska earthquake known to have been recorded, and it had a double amplitude of 0.37 foot. Only 7 surface-water recorders out of 150 or so in operation gave noticeable evidence of the Alaska earthquake. Gaging stations close to those that were affected went through the period without recording the slightest change. Three gages that responded noticeably to the earthquake each showed (fig. 6) a sudden drop in stage with complete recovery in 15–30 minutes. There was no rise above normal level at any of the three stations. These three hydroseisms were recorded at stations equipped with bubbler gages, so the response probably reflects instrumental failure to record rapid fluctuations. Thus, some interesting-looking records of the earthquake may be worthless as far as indicating true water-level response to the seismic waves.

KENTUCKY

Twenty hydroseisms were recorded in a total of 60 observation wells in Kentucky, but only one well had a fluctuation greater than 1 foot. This well is at Mammoth Cave National Park.

Four seismic seiches were recorded by gages. The largest, 0.57 foot, was recorded on Buckhorn Reservoir at Buckhorn. The next largest, 0.40 foot, was recorded on Nolin River Reservoir near Kyrock.

The Louisville Courier-Journal (Mar. 31, 1964) carried an article describing the effect of seismic seiches on two other Kentucky lakes:

> Witnesses said water about 4 miles from Dix Dam at Lake Herrington slopped around like it does in a dishpan, but people at either end of the lake reported nothing unusual.
>
> The superintendent of Lake Cumberland State Park confirmed * * * reports by fishermen of a series of mysterious waves that swept across Lake Cumberland at about the time of the Alaska quake. Superintendent John Flanagan said the waves were a foot to 18 inches high, and snapped two cables on the Jamestown boat dock. Other reports told of the lake falling and rising from 3 to 4 feet several times. The boat-dock operator called up and said the lake was acting funny—calm in the middle but whirling in circles near the shore.

LOUISIANA

A total of 37 hydroseisms was reported from Louisiana wells with double amplitudes ranging from 0.04 foot to greater than 5 feet. One record (EB–90) is from a well 2,120 feet deep cased to 2,025 feet; this is the deepest well in the Nation from which a hydroseism was reported. Eight identifiable aftershocks were recorded in 1 well (SJB–17). In no other well in the State are aftershocks known to have been recorded.

Seismic seiches along the gulf coast and in the bayous were large enough to cause destruction. The New Orleans States-Item (Mar. 28, 1964) reported:

> Boats were sunk and some roads in communities close to the Gulf of Mexico were flooded by a wave that rolled in, then subsided. Other boats were torn from their moorings. At Golden Meadow on Bayou Lafourche a big oyster vessel was thrown against a store building on the bayou. For a brief instant a

foot and a half of water covered roads on both sides of the bayou at Golden Meadow and neighboring Galiano. Grand Isle, located right on the Gulf, apparently didn't get a ripple from the strange wave action. At Delacroix Island, where several boats were washed from their moorings, one man crawled along his dock to land on hands and knees to keep from getting washed away by the tide.

Between midnight and 01:00 c.s.t. on March 28, 1964, in the midst of a TV bulletin giving the first news of the Alaska earthquake, a special bulletin announced that a tidal wave had struck the Louisiana coast, sunk small boats in Chef Menteur pass, and is now entering Lake Pontchartrain.

A large barge-mounted drilling rig on location in Lake Ponchartrain at lat 30°09.6′ N. and long 89°56.8′ W. experienced a seismic wave also. The barge was lifted approximately 2 feet as tanks were being flooded to sink it to the bottom. Only one wave was noted. Tugs in the Industrial Canal, which with the Gulf Seaway connects Lakes Pontchartrain and Borgne, reported they experienced momentary tides of 6 feet or more (Rex Meyer, written commun., June 12, 1964).

Almost all the gages throughout Louisiana recorded seismic seiches from the Alaska earthquake. The largest was 0.90 foot in double amplitude. Many others were of large size, but none showed a coda portion lasting more than an hour.

MAINE

One hydroseism of 0.19 foot was recorded in a well at Brunswick, Maine. This is one of the few hydroseisms recorded in the New England States. No surface-water gages in the State showed any effect of the quake.

MARYLAND

The earthquake was recorded in four wells in Maryland. Although the four all bottom in sand aquifers, the response of one was markedly different from the other three which showed normal hydroseisms. In the fourth well (Dor-Cd 40) the water-level dropped 0.20 foot during a 25-minute period, but this drop is coincident with a decline due to earth tide, and it is impossible to separate visually the effect of each.

The earthquake was also recorded at three gages on streams, but the maximum fluctuation was only 0.04 foot.

MASSACHUSETTS

The earthquake was recorded in one well in western Massachusetts. The well, which penetrates Stockbridge Limestone, registered a fluctuation of 0.62 foot.

MICHIGAN

The State of Michigan reported 48 hydroseisms in wells—second only to Florida in the number reported; however, only two wells recorded aftershocks. A well in Genessee County, which recorded three aftershocks, is unusual in that it bottoms in an old water-filled coal mine. This type of construction may possibly be favorable for recording hydroseisms because many have been reported from this well over the years.

Two partly buried reservoirs owned by the city of Lansing and equipped with recording gages showed seismic seiches. In one reservoir, having a capacity of 7 million gallons, a fluctuation of 1.84 feet was recorded; in the other, having a capacity of 10 million gallons, a 1.25-foot fluctuation was recorded. The time of occurrence at Lansing was 03.55 G.c.t. on March 28.

The 16 seiches recorded at gaging stations were all small; the largest was 0.06 foot in double amplitude. Lasting changes in stage were recorded at two gages: a 0.01-foot drop on the Cedar River at East Lansing and a 0.01-foot rise on the Cass River on the northern peninsula of Michigan.

MINNESOTA

Although some of the 15 hydroseisms reported from Minnesota were rather large, no aftershocks were recorded. In each of two wells in Hennepin County, the water level declined 2 feet in 40 hours following the earthquake. This decline may have been caused by local pumping, but the similarity of record and the timing suggest that the response may represent some local effect induced by seismic waves from the earthquake. In another well, the water level changed so rapidly that the ink of the pen did not flow fast enough to give a complete record.

Only one seiche was reported from surface-water gages in Minnesota. It had a double amplitude of 0.03 foot and was recorded on the Roseau River at Ross.

MISSISSIPPI

The instruments on observation wells in Mississippi recorded 11 hydroseisms. Of these, five were on or near the Tatum salt dome. The response was somewhat anomalous in that the water level declined instantaneously and then took several hours to rise to the preearthquake level.

Of the 22 hydroseisms reported from surface-water gages in Mississippi, all were recorded as seismic seiches, and 10 had double amplitudes of 0.10 foot or greater The largest seiche, 0.90 foot, was recorded on the Pearl River gage at Monticello.

MISSOURI

Of the 28 hydroseisms in wells reported from Missouri, some were quite large and others were quite unusual. One well in Greene County had a fluctuation greater than 10 feet and, following the earthquake, the water level rose 50 feet between March 28 and June 2, 1964. The same reaction but on a smaller scale occurred in Madison County where well 33N/7E–20bcd had a water-level rise of 5.55 feet in the first 40 hours after the earthquake and an additional 1.65 feet of rise in the next 98 hours. In Polk County well 33N/Z1W–5adc the water level fell 1.1 feet in 1½ hours after the quake.

The largest seiche of 0.87 foot was recorded by the Black River gage at Poplar Bluff, but no coda portion was recorded.

Several stations in Missouri equipped with bubbler gages recorded the earthquake, but water-level change was recorded either as an upward or downward motion, never as both up and down, evidently because of the relative unresponsiveness of this type of instrument.

According to Fellows (1965), many home wells and the municipal wells at Rogersfield and Mansville, in southwestern Missouri, yielded turbid water, some of it reportedly "blood red," for a few hours to a few days following the earthquake.

Fellows (1965, p. 3, 4) reports further that:

> Within two months after the quake, static water levels in two deep wells in Springfield rose by several tens of feet. Unfortunately, these wells were not equipped with automatic depth recorders and static water levels were not determined at regular intervals.
>
> Fishermen at Table Rock Lake in Taney County, Mo., observed mysterious waves on the lake the night of the quake.

MONTANA

Hydroseisms were recorded in only three wells in Montana. In one of these wells (Gallatin County well A1–4–25dc) the response was greater than 1 foot for the main quake, and seven of the major aftershocks were recorded. The recorder on this well in alluvium at Bozeman has been maintained for many years by Dean C. C. Bradley of Montana State College and has registered many other earthquakes.

The Billings Gazette (Mar. 30, 1964) reported that a "small wave developed on Hauser Lake northwest of Helena a few minutes after the Alaska quake and tore a boat dock from its moorings."

Of the 21 hydroseisms from stream-gaging stations in Montana, the largest double amplitude was 0.16 foot. Practically all the records came from the mountainous part of the State, and none were recorded on the main stem of the Missouri River. Gages on the North Fork of Milk River and Sage Creek, both on the international boundary, showed a rise in water level of 0.01 or 0.02 foot at the time the earthquake was recorded at other gages.

NEBRASKA

The largest hydroseism in Nebraska for the seven wells reported was 4.10 feet, but no aftershocks were recorded. This well had a fluctuation 18 times as great as that which was recorded for the Hebgen Lake, Mont., earthquake of August 17, 1959. A well in Thayer County (4–1–9bac) had an unusual response: The water level rose 0.87 foot but at no time declined below the prequake level.

The 14 hydroseisms from Nebraska stream gages were all recorded as seismic seiches. This response was unusual in that seiches were sparsely recorded elsewhere in the northern Great Plains.

NEVADA

All five of the hydroseisms recorded in Nevada were in Clark County wells. The one in well S19/60–9bcc caused the recorder drum to make a complete rotation, and four of the major aftershocks were recorded. This record is to be expected because hydroseisms have consistently been clearly recorded in this well.

NEW HAMPSHIRE

Hydroseisms were not recorded in New Hampshire wells, but one surface-water gage registered the earthquake.

NEW JERSEY

A total of 40 hydroseisms was reported from wells in New Jersey. Of these, only six had fluctuations greater than half a foot. The maximum fluctuation, 4.37 feet, occurred in Hillside well 4 in Union County. One distinct aftershock was recorded by this well, which is the one in New Jersey most sensitive to earthquake shocks.

Only one somewhat questionable hydroseism was recorded by a surface-water gage in New Jersey. The large number of wells that responded to the quake seem in odd contrast to the one questionable record from a stream gage.

NEW MEXICO

In New Mexico hydroseisms were recorded at 12 observation wells. Of these, two had fluctuations of more than 5 feet, but neither one showed any aftershocks. The Hot Springs well 6 in Sierra County had a fluctuation of more than 1 foot, and some aftershocks were registered. The main shock thus may have caused the recorder drum to rotate many times, so the actual fluctuation must have been considerably greater than 5 feet. At another well the motion caused the pen to pull the paper off the recorder, and in another the motion was so rapid that the ink could not flow fast enough to give a complete record.

C. V. Theis (written commun., Aug. 4, 1964) furnished the following comments:

In New Mexico, the Alaska earthquake produced a fluctuation of the Greenfield observation well in the Roswell artesian aquifer of about 13 feet. This well is comparatively shallow, is just below the lip of the confining beds, and is in a part of the aquifer with transmissibility in the millions. The Artesia recorder well, located where the aquifer is deeper, with a transmissibility of only 100,000 or so, and where the strata are becoming more calcareous near the old reef, had a fluctuation of only a small fraction of a foot. * * * Lea Lake, east of the Pecos and approximately east of Roswell, the largest of the Bottomless Lakes, about 300 feet deep, and an acre or so in surface area, produced a water spout said to be about 15 feet high. Maddox [U.S. Geol. Survey, Roswell] saw old tires and other objects floating on the surface of the lake the next day, these having been cast up from the bottom. The brine observation wells at Malaga Bend near Carlsbad, which fluctuated about a foot from the Turkish earthquake of about 1939, lost the record of the Alaskan quake because the pen of the Friez recorder was thrown over the cylinder.

Roy Foreman, who runs a concession at Lea Lake, N. Mex., observed the effects of the Alaska quake on the lake and the following is a summary of his observations:

About 9:40 p.m., March 27, 1964, waves about 10 feet high rose on Lea Lake. At this time my wife and I heard a loud noise, which sounded like a strong wind although it was a calm evening. The water flowed over a 3-foot high guardrail which is 54 feet from the normal port margin. A section of the guardrail was washed out by the flow of water.

Before the earthquake a small trickle of water flowed from the lake through a 12-inch culvert. The morning after the quake, the 12-inch culvert was carrying a full capacity of outflow. The discharge as of August 1964 was still more than the prequake discharge.

In the Carlsbad area, 6 of 21 gages on flowing streams recorded hydroseisms, but the 6 hydroseisms recorded were all of small double amplitude. Elsewhere in the State, 21 hydroseisms were recorded of which 19 were seismic seiches and 2 were minor changes in stage.

NEW YORK

Nine hydroseisms were recorded in New York State wells. These did not include Saratoga 529 and Queens 64 which previously had shown rather outstanding responses to earthquakes. Recorders had been removed from both these wells before the Alaska earthquake. The Chautauqua 10 well, however, had a fluctuation of 2.10 feet and also recorded one aftershock. It is interesting to note that this well had a fluctuation of 0.22 foot for the Hebgen Lake earthquake of August 17, 1959. At another well, the recorder pen failed during the Alaska quake.

Only four seiches, each less than 0.01 foot, were recorded at stream gages in New York State. In addition, one record from the Mahwah River near Suffern showed a drop in stage of about 0.01 foot.

NORTH CAROLINA

Three hydroseisms were reported from North Carolina wells; the largest hydroseism had a double amplitude of 1.85 feet.

NORTH DAKOTA

North Dakota reported three hydroseisms from wells that penetrate glaciofluvial sand and gravel.

The earthquake was also recorded at two surface-water gages in the State. The record from one, on the Cheyenne River near Kindred, is questionable in that it seemingly was made an hour earlier than it should have although this may be due to clock error. The record looks like a seiche of 0.05 foot double amplitude followed immediately by a decline in stage of 0.02 foot. The other gage, on Jamestown Reservoir near Jamestown, showed a rise in water level of 0.07 foot in about 10 minutes, declined 0.05 foot during an approximate 20-minute interval, and then remained steady for the next 9½ hours.

OHIO

Observation wells in Ohio recorded 32 hydroseisms from the Alaska earthquake. The largest fluctuation was 5.8 feet in a well in Van Wert County. Even with so large a fluctuation, the aftershocks were not strong enough to be recorded, perhaps because the gage-scale gears were 1:10, and the record was so compressed that the minor fluctuations were obscured.

A total of 188 analog recorders was in operation in Ohio at the time of the Alaska earthquake, but only 25 showed any noticeable effects. The seismic seiches probably were obliterated at a few of the gaging stations because of normal river surging or fluctuation caused by wind action. The maximum double amplitude was 0.25 foot on a lake gage near Jefferson, Ohio. Another gage, 800 feet away on Mill Creek, recorded a sharp drop in stage of 0.04 foot followed by a rapid rise of 0.03 foot. The water level then remained steady at this slightly lower level. The Mahoning River gage at Alliance, Ohio, showed a drop of 0.01 foot at the time of the earthquake. One other gage, at Atwood Reservoir near New Cumberland, also showed a similar reaction.

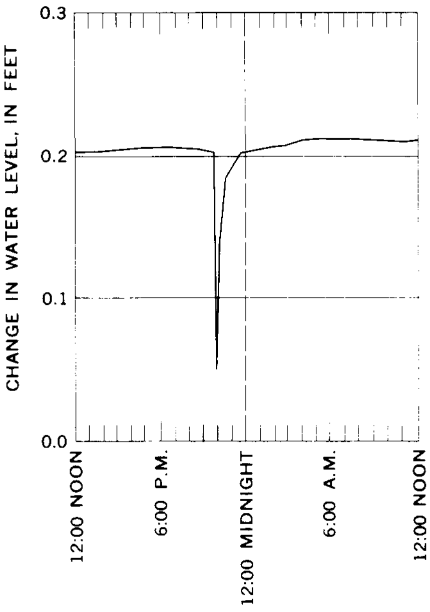
OKLAHOMA

Hydroseisms were noted in wells equipped with water-level recorders in the Oklahoma Panhandle, central, and eastern parts of the State. The fluctuations in water levels were more than 1 foot in wells in the panhandle, in Grady County, and in the Arbuckle Mountains; about 0.4 foot in a well in Washita County; and about 0.1 foot in one in the Arkansas Valley.

Hydroseisms are tabulated for six observation wells (table 7). In one well the water movement was so rapid that the beaded cable slipped on the pulley of the recorder. Two wells in sec. 25, T. 6 N., R. 18 E. provide an interesting contrast. Both penetrate the Ogallala Formation to a depth of 99 feet, and both are equipped with recorders which show similar responses to barometric changes and rainfall. However, one showed rapid water-level fluctuations due to the earthquake, whereas the other showed no response.

At Byrd Mill Spring south of Ada, a surface-water pool showed a drop of 0.15 foot in water level at the time of the quake, and it took about 1½ hours to recover to the preearthquake level (fig. 22). The spring originates along a faulted limestone section in the Arbuckle Group and seemingly the shock wave for a time partly closed the opening along which water flows to the spring.

A total of 45 seismic seiches caused by the Alaska earthquake was recorded in Oklahoma. Of these, the largest had a 0.44-foot double amplitude recorded on Lake of the Cherokees at Langley. Minor decline in stage seemingly caused by the earthquake occurred at gages on Little River near Wright City, Muddy Boggy Creek near Farris, and Verdigris River near Inola. A slight rise in stage seemingly caused by the earthquake occurred at the gage on Sallisaw Creek near Sallisaw. The decline and recovery of water level as described above for Byrd Mill Spring Pond was also recorded at four other gages, but the maximum decline was only 0.04 foot. These four gages are on Lake Texoma near Denison, Tex.,



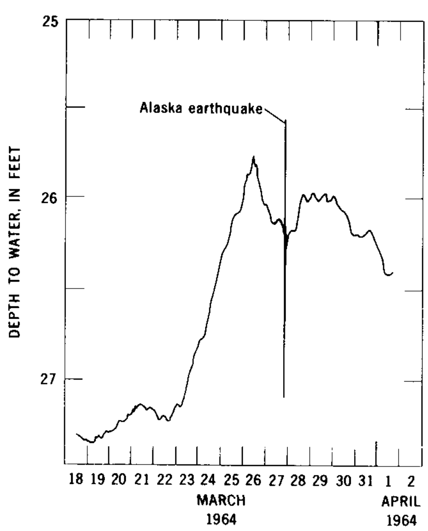
22.—Effect of the Alaska earthquake on the surface-water pool formed by Byrd Mill Spring, Okla. Central standard time.

Glover Creek near Glover, Okla., Sand Creek at Okesa, and Verdigris River near Claremore.

OREGON

Only one hydroseism of 0.055 foot was recorded in Oregon wells; however, only three well recorders were in operation at the time of the quake. Inasmuch as Oregon is fairly close to Alaska, unrecorded water-level fluctuations probably occurred in many wells.

Seismic seiches were recorded by eight gages in Oregon. The largest had a double amplitude of 0.14 foot.



23.—Hydroseism from well Yo 180 in York County, Pa. Eastern standard time.

PENNSYLVANIA

Among the 19 hydroseisms reported from Pennsylvania wells are some that are unusual. The earthquake records in seven wells in Dauphin, Luzerne, and York Counties all were at the bottom of a "low" superimposed on a water-level "high." This type of response may have been caused by local barometric changes rather than by the earthquake (fig. 23).

A stream gage on Paxton Creek did not record a seiche but it registered a sudden increase in stage 13 hours after the quake. No rain was reported in the basin. This rise in stage may represent water squeezed from an aquifer cropping out upstream (fig. 7).

Only two seismic seiches were recorded in Pennsylvania although 102 gaging stations equipped with analog recorders were in operation at the time. The double amplitudes recorded were 0.05 and 0.04 foot.

PUERTO RICO

Of the four hydroseisms reported from wells in Puerto Rico, one was surprisingly large. The fluctuation measured 3.40 feet and was recorded so fast that the beaded cable slipped on the pulley. This well (Jauca 2) is in a graben near a fault zone.

RHODE ISLAND

No trace of the Alaska earthquake was recorded either at observation wells or surface-water gages in Rhode Island.

SOUTH CAROLINA

The hydroseisms recorded from South Carolina were large. In Beaufort County well 304, the recorded fluctuation was 8.98 feet, but the beaded cable was thrown off the pulley, so the fluctuation may have been even larger. Because of this disruption, no aftershocks were recorded; however, Jasper County well 46, which had a fluctuation of only 4.72 feet, recorded five aftershocks.

Seismic seiches were recorded by eight gages in South Carolina. The largest double amplitude was 0.12 foot.

SOUTH DAKOTA

Only two hydroseisms were reported from South Dakota, but one is the largest recorded for this quake in any well outside of Alaska. This one was recorded on a pressure recorder in a test well drilled to an artesian aquifer, which had an original pressure head of 266 feet above land surface. At the time of the quake the pressure head was 121 feet above land surface, so a pressure recorder of 200 feet capacity was mounted on the well. This unusual situation permitted the full range of the Alaska earthquake-pressure effect of 23 feet to be recorded in the well. The well produces from sandstone of the Opeche (Permian) and Minnelusa (Pennsylvanian and Permian) Formations and is at the northwest edge of the Black Hills. Because 4½ inches on the chart represents 200 feet of pressure, it is not surprising that no aftershocks appear on the chart.

Six seismic seiches were recorded by gages in South Dakota. The maximum double amplitude was 0.14 foot.

TENNESSEE

The following information concerning Tennessee wells is extracted with slight modification from a paper by Hassler (1965): Hydroseisms recorded at Geological Survey wells ranged from a trace to 3.90 feet. The shock was so violent that recorder pens were flipped off the charts at Jellico and New Johnsonville. Two major aftershocks on March 29 and 30 were also recorded at the Capleville (J–1) well. Only two wells (Sloanville, U–1 and U–2) were equipped with Stevens A–35 recorders with large time scales (2.4 in. per day). Records from these instruments indicate the first waves arrived at approximately 10 p.m. c.s.t., and the major fluctuations occurred about 20 minutes later. Water levels in both wells fluctuated for about 3 hours after the major shock.

Hassler (1965) also reported that seismic seiches were recorded at approximately 20 percent (22 gages) of the surface-water gaging stations equipped with analog recorders. This figure would probably be much higher had not many streams been receding from fairly high stages at the time the quake occurred. The duration of the oscillations ranged from about 5 minutes to 35 minutes.

The three largest seiches in the State were all recorded at gages on the Cumberland River: 0.36 foot at Carthage, 0.42 foot below Old Hickory, and 0.42 foot at Rome. The other seiches recorded were all much smaller; ranged from 0.10 to 0.14 foot, and 13 were less than 0.10 foot.

In Dickson, Knox, and Montgomery Counties, muddy water was reported in many wells tapping the Fort Payne Chert. The quake coincided with a period of heavy precipitation, so it is not known whether the heavy rains, the earthquake, or a combination of both produced the muddy water in wells.

TEXAS

Data on some of the hydroseisms from the Alaska earthquake as recorded in Texas wells have already been published. Miller and Reddell (1964) list five wells in the High Plains area that recorded such fluctuations. Montgomery (1964) describes three from wells in Bexar County. Mills (1964) lists 28 recorded in U.S. Geological Survey observation wells in Texas; the data from these 28 records are included in table 7. Aftershocks are known to have been recorded in only two Bexar County wells—five in one and four in the other. Most of the largest hydroseisms occurred in wells penetrating the Edwards Limestone.

A list of seismic seiches in Texas compiled by W. B. Mills (written commun., November 1964) shows that 69 gages were affected by the earthquake. The up and down amplitudes were all equal except for Lake Winnsboro near Winnsboro where the entire motion was down (0.03 ft). The largest double amplitude was 0.68 foot recorded at Sabine River near Ruliff. The next largest was 0.64 foot recorded on Angelina River near Zavalla. The duration of the disturbance at both of these stations was 60 minutes. At Lake Houston near Sheldon, the double amplitude was only 0.13 foot, but the disturbance continued for 90 minutes.

The earthquake was recorded at two stations equipped with bubbler gages: one on the Guadalupe River at Cuero and the other on the Nueces River at Mathis. Both gages recorded only a downward motion of the water level, 0.29 foot at the former and 0.06 foot at the latter. The bubbler gages have a built-in delay of a few seconds. The gages probably responded to the first motion to reach them and were unable to respond quickly enough to the upward surges of the seiche. Consequently, the records of these gages may be proof that the first motion to affect them was a decline in water level.

UTAH

Fourteen hydroseisms were recorded on observation wells in Utah. Of these, two were on pressure recorders, but the 2-foot and 1.2-foot fluctuations recorded are small compared to the 23 feet for the pressure recorder in South Dakota. Two wells recorded aftershocks: seven in a Tooele County well and one in a Weber County well. Both wells were equipped with recorders that would measure a maximum fluctuation of 1 foot—less than the fluctuation for the main quake. A well that had a measurable fluctuation of 2.50 feet seemingly recorded one aftershock, so the fluctuation in the others probably was more than 2.5 feet.

Eight seismic seiches were recorded at gages in Utah. The largest was 0.06 foot in double amplitude. The others were minor, ranging from 0.01 to 0.03 foot.

VERMONT

Two seismic seiches were recorded in Vermont. The larger seiche, at the Wrightsville Detention Reservoir gage, had a fluctuation of 0.23 foot. The smaller, at the East Barre Detention Reservoir gage, had a fluctuation of 0.06 foot. The general lack of hydroseisms at both wells and stream gages in New England makes it surprising that these were recorded. The gages were both on reservoirs; no seiches were recorded on streams anywhere in New England.

VIRGINIA

One well in Virginia recorded the Alaska earthquake. The well is at Shenandoah National Park, is 280 feet deep, and penetrates metabasalt of the Catoctin Formation of Precambrian(?) age. The total fluctuation was 1.60 feet, which is divisible into a rise of 0.45 foot, an upward displacement of the water level of 0.55 foot that apparently occurred at the time of maximum fluctuation, and a decline of 0.60 foot.

No surface-water gages in the State showed a trace of the earthquake.

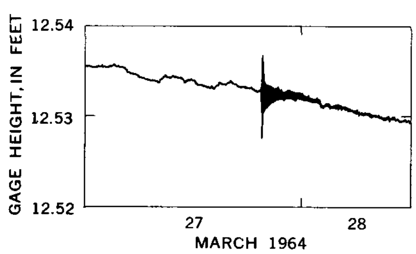
VIRGIN ISLANDS

The most distant hydroseism to be recorded in United States territory was a 0.05-foot fluctuation in a well in the Virgin Islands.

WASHINGTON

Seven hydroseisms were reported from Washington, of which one had a fluctuation of 3.92 feet and was followed by six aftershocks. The other hydroseisms were all relatively small in amplitude and none was followed by aftershocks. In one well, which had an instantaneous fluctuation of only 0.16 foot, the water level rose 1.20 feet during a 4-hour period immediately after the quake and then stayed at this higher level.

The gage on Snohomish River at Snohomish showed a strong fluctuation of about 0.45 foot superimposed on a much larger tidal cycle. This fluctuation occurred at 03:50 G.c.t. on March 27, so it undoubtedly was caused by waves from the earthquake.



24.—Seismic seiche and wind seiches at Franklin D. Roosevelt Lake at Grand Coulee Dam, Wash. Pacific standard time.

The gage on Franklin D. Roosevelt Lake at Grand Coulee Dam recorded an interesting seiche (fig. 24). Prior to the seismic seiche a long train of wind seiches had been recorded. Four other smaller but typical seismic seiches were recorded elsewhere in the State.

Several atypical seismically caused water changes were recorded at other gages in Washington. At Whitestone Lake near Tonasket, the gage recorded a sudden 0.03-foot rise of water level followed by the recording of a seiche. Slight residual upward changes in water level were recorded at two gages, and slight temporary changes were recorded at three other gages. The gage at Lenore Lake near Soap Lake recorded seiches from wind all day on March 27, but beginning at 8 p.m. P.s.t. the Alaska earthquake surface waves increased the amplitude of the seiches.

WEST VIRGINIA

Only one hydroseism was found in West Virginia, and it was recorded in a well at the extreme east tip of the State (see table 7). This well in Berkeley County penetrates Beekmantown Limestone of Ordovician age and had a 0.30-foot fluctuation.

WISCONSIN

Of the 17 hydroseisms recorded in Wisconsin, the most detailed is the partial record obtained by E. E. Rexin at the well of the Nunn-Bush Shoe Co. in Milwaukee, discussed on page C10.

In three wells, the water level rose and stayed at the higher level. In the Nunn-Bush Shoe Co. well there was an apparent rise of about 12 feet. In another Milwaukee County well the water level rose 7.3 feet after the quake. In a Monroe County well the water level rose 1.43 feet and remained at this level.

Six surface-water gages in Wisconsin recorded small seiches caused by the Alaska earthquake. The largest seiche was 0.02 foot, and the others were barely visible on the charts. Both the small size and the small number of seiches that were recorded at surface-water gages contrast markedly with the large size and the large number that were recorded at wells.

WYOMING

The Alaska earthquake was recorded in two observation wells in Wyoming. In one the motion was about 2 feet, but no aftershocks were recorded.

The earthquake was recorded at nine stream gages, all in western Wyoming. Thus the distribution of the records corresponds to the distribution in Colorado where effects were recorded only in the western part of the State.

HYDROSEISMS FROM AFTERSHOCKS

The Alaska earthquake generated literally thousands of aftershocks, but few of the major aftershocks occurred near the epicenter of the main shock. Instead, many occurred 2°–8° southwest of the epicenter, and practically none occurred to the northeast. A magnitude-8.4 earthquake normally would have generated a few shocks of magnitude 7, but the largest magnitude of any of the Alaska aftershocks was 6.6. Those aftershocks that generated a hydroseism in one or more wells are listed in table 5. Two other earthquakes that occurred during the period from March 28 to April 4, 1964, and that generated hydroseisms are also listed. One occurred on March 31 in the Queen Charlotte Islands of British Columbia. The other occurred on April 3 off the northwest coast of Sumatra.

The aftershocks were not recorded consistently in wells. For example, of the two aftershocks of magnitude 6.6, the one on March 28 at 20:29 G.c.t. was recorded in 14 wells, but the one on March 30 at 02:18 G.c.t. was recorded in 30 wells. Some of the aftershocks reported as having been recorded in one, two, or three wells may have been misidentified.

The aftershocks were recorded in only about 4 percent of the wells in which the main shock was recorded. In general, those wells that recorded the aftershocks are those in which earthquakes are best and most frequently recorded. No aftershocks were recorded at any surface-water gages outside of Alaska. The aftershock records from the more seismically sensitive wells are listed in table 6.

TABLE 5.—*Earthquakes recorded in seismically sensitive observation wells, March 27–April 4, 1964*

Date	Epicentral time (G.c.t.)	Epicenter		Magnitude measured at Pasadena	Number of wells in which recorded
		North latitude (°)	West longitude (°)		
March 28	03:36:12.7	61.05	147.5	8.4	713
	09:01:00	56.5	152.0	6.2	3
	09:52:54	59.7	144.6	6.2	5
	10:35:39	57.2	152.4	6.3	5
	11:08:26	60.1	148.5	6.2	1
	12:20:49	56.5	154.1	6.5	24
	14:47-14:49	60.4	146.5–147.1	6.3–6.5	16
	20:29:06	59.8	148.9	6.6	14
March 29	06:04:43	56.2	154.2	5.8	4
	16:40:59	59.8	146.9	5.8	5
March 30	02:18:06	56.6	153.0	6.6	30
	07:09:34	59.8	145.9	6.2	19
	13:03:35	56.5	152.7	5.3	1
	16:09:27	56.6	152.2	5.5	1
March 31	09:01:33	50.8	130.1	6	[1] 20
April 2	01:11:56	6.1	[2] 95.4	7	[3] 3
April 3	22:33:39	61.7	147.7	6	2
April 4	17:46:08	56.3	154.5	6½	11
	22:16:57	59.5	145.0	Not reported	1

[1] Earthquake in Queen Charlotte Islands, British Columbia.
[2] East.
[3] Earthquake off northwest coast of Sumatra.

TABLE 6.—*Seismic fluctuations in sensitive wells, March 28–April 4, 1964*

[Greenwich civil time]

State, county, and well	Fluctuations, in feet																		
	March 28								March 29		March 30				Mar 31	Apr 2	Apr 3	April 4	
	03:36	09:01	09:52	10:35	11:08	12:20	14:47 and 14:49	20:29	06:04	16:40	02:18	07:09	13:03	16:09	09:01	01:11	22:33	17:46	22:16
Arizona:																			
Yuma, (c-11-24)23bcb	>1	------	------	------	------	0.025	------	------	------	------	0.014	0.005	------	------	0.003	------	------	0.01?	------
Florida																			
Taylor, 35	[1] 17	------	------	------	------	.15	0.20	0.05	------	------	.10	.04	------	------	.06	------	------	.12	------
Georgia:																			
Dawson, 12-3	>1	0.042	0.018	0.014	------	.020	.014	Tr.?	------	------	.02	.005	------	------	Tr.?	------	------	.012	------
Dougherty, 13L4	>5	------	------	------	------	.065	.035	.054	------	0.02	.054	.016	------	------	.03	0.02	------	.048	------
Mitchell, 10G313	>5	------	------	------	------	.05	.046	.034	------	------	.072	.042	------	------	.036	------	------	.05	0.016
Hawaii:																			
Oahu, 83	1.85	------	------	------	------	.05	.005	------	0.008	------	.006	------	------	------	.04	------	------	------	------
Idaho:																			
Cassia, 35-21E-18bb1	1.44	------	------	------	------	.04	------	------			Tr.								
Latah. 39N-4W-7	>5	------	.05	------	------	.10	.05	.14	Tr.	.05	.10	.06	------	------	.14	.05	0.04	.05	------
Illinois:																			
DuPage, ANL-10	7.70	------	------	------	------	Tr.?	.025	------	------	------	.07	------	------	------	.03	------	------	------	------
Indiana:																			
Marion, Ma-32	>1	.021	.020	.021	0.027	.052	.034	.040	.008	.005	.21	.044	------	------	.011	------	.018	.066	------
Pulaski, Pu-6	>1	------	------	------	------	------	------	------	------	------	.03	.02	------	------	------	------	------	------	------
Louisiana:																			
St. John The Baptist, SBJ-17	>1	------	------	------	------	------	------	------	------	------	.058	.012	------	------	.008	------	------	.010	------
Michigan:																			
Genesee, 7N-7E-17-1	>2	------	------	------	------	.076	.032	------	------	------	.08	------	------	------	.02	------	------	.072	------
Kent 6N-12W-34-1	>5	------	------	------	------	------	------	------	------	------	.02	.012	------	------	------	------	------	------	------
Missouri:																			
Barton, 32N/30W-30cd	>5	------	------	------	------	.07	.05	.04	------	(2)									
Franklin, 44N/1W-27	>3.90	------	------	------	------	.04	------	------	------	------	.04	------	------	------	------	------	------	------	------
Montana:																			
Gallatin, A1-4-25dc	>1	------	------	.009?	------	.002	.02	------	------	------	.026	.024	------	------	.05	------	------	.006	------
Nevada:																			
Clark, S19/60-9bcc1	>1	------	------	------	------	.03	(3)	.014	------	------	.022	------	------	------	.016	------	------	------	------
New Jersey:																			
Union, Hillside 4	4.37	------	------	------	------	Tr.	------	------	------	------	.06	------	------	------	------	------	------	------	------
New Mexico:																			
Sierra, Hot Springs 6	>1	.012	------	.005	------	.04	(3)	.024	------	------	.166	.02	------	------	.06	------	------	------	------
New York:																			
Chatauqua, Cu-10	2.10	------	------	------	------	------	------	------	------	------	.04	------	------	------	------	------	------	------	------
Pennsylvania:																			
Luzerne, Dennison St. borehole	>2	------	------	------	------	.06	.04	------	------	------	.076	.020	------	------	.022	------	------	------	------
South Carolina:																			
Jasper, 46	4.72	------	------	------	------	.03	.035	.015	------	------	.03	.025	------	------	.01	------	------	------	------
Tennessee:																			
Shelby, Sh:J-1	2.27?	------	------	------	------	------	------	------	------	------	.034	------	------	------	------	------	------	------	------
Texas:																			
Bexar, F-172	>5	------	------	------	------	.06	.01	Tr.?	------	------	.05	------	------	------	------	------	------	.04	------
J-17	>3.80	------	------	------	------	------	------	------	------	------	.02	------	------	------	------	------	------	------	------
Jackson, PP-80-03-101	[1] 5.8	------	------	------	------	------	------	------	------	------	.04	.01	------	------	.02	.02	------	------	------
Utah:																			
Tooele, (C-3-2)14bad-1	>1	------	.007	------	------	.014	Tr.	Tr.	------	------	.032	Tr.	------	------	.025	------	------	------	------
Weber, (B-6-1) 30cca-1	>1	------	------	------	------	.012	.004	.005	Tr.	Tr.	.022	.007	------	?	.018	------	------	------	------
Washington:																			
Pierce, 20/3-18c1	3.92	------	------	------	------	.03	------	.03	------	------	.08	.03	------	------	.07	------	------	------	------
Wisconsin:																			
Milwaukee, M1-120	------	------	.016	.045	------	.037	------	------	------	.02	.062	.048	0.002	0.0022	------	------	------	------	------

[1] Estimated. [2] Pen ran out of ink? [3] Masked by water-level change.

CONCLUSION

This report is the first in which hydrologic effects of a major earthquake have been gathered from throughout the world. Little attempt has been made at interpretation because the major effort so far has been concentrated on assembly of the data. Interpretive studies will possibly show that the areal distribution of effects has some significance. Several interpretive studies are in progress but are not ready.

The theory of "The response of well-aquifer systems to seismic waves" as developed by Cooper and others (1965) goes far toward explaining seismic fluctuations in wells, but no theory as yet explains adequately the lasting change in water level that was observed in many wells. Similarly no theory accounts for the asymmetry of water-level response in wells. The theory of Cooper and others assumes seismic waves to be sinusoidal, whereas some well records show only a brief rise or fall from static level.

Theory as yet explains adequately neither the "draining" of a piezometric high nor the observed "recharging" of a cone of depression, phenomena that were both observed in the weeks immediately following the Alaska earthquake. Thus there is still a gulf between theory and observation.

Similarly, the rigorous mathematical interpretation of seismic seiches by McGarr (1965) goes far toward explaining the many seiches that were recorded. However, one of the two major factors which he states (p. 853) "help to convert the energy of large-magnitude earthquakes efficiently to produce seiches at large distances from the epicenter" is "a very thick layer of soft sediments." According to McGarr (1965), this layer serves to amplify the seismic motion and especially the horizontal ground acceleration. This factor seemingly is minimal in importance or nonoperative in Colorado, Wyoming, and Vermont. In the western half of both Colorado and Wyoming many seiches were recorded, and two were recorded in Vermont, places where sedimentary deposits are thin to absent, but in eastern Colorado, eastern Wyoming, and through the northern Great Plains, no seiches were recorded although this area is underlain by a sizable thickness of such deposits. Thus, there is also a gulf between theory and observations concerning seismic effects on surface-water bodies.

It is hoped that the data presented in this report will encourage further studies so that the discrepancies that exist between theory and observation can be narrowed and ultimately bridged.

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TABLE 7.—*Hydroseisms in wells in the United States caused by the Alaska earthquake*

Depth to water: Depth in feet below land surface unless otherwise indicated; a preceding plus sign indicates height of the piezometric level above land surface; a preceding plus or minus sign in parentheses indicates depth to water above (+) or below (−) sea level. LSD, land surface datum. Figure in parentheses following depth to water is rise (if plus) or fall (if negative) from the preearthquake to postearthquake water level; this change where reported is not due to water-level trend but is either change in stress on the aquifer caused by the earthquake waves or excessive friction in the recorder installation.

Water-level fluctuation: E, estimated.

Remarks: Because aftershocks can be expected to record only in wells with the largest hydroseisms, failure to record aftershocks is mentioned only for those wells in which aftershocks might have been recorded. Recorder character as to inches of chart per day and gage-height ratio are given only for wells whose charts were examined by the compiler. T, transmissibility; S, coefficient of storage. Other data are as reported.

County, well	Latitude, N.	Longitude, W.	Water-bearing formation	First number, depth of well; second, depth of casing to screen, perforated casing, or open hole (feet)	Depth to water (feet)	Water-level fluctuation (feet): From preearthquake level: Upward	Water-level fluctuation (feet): From preearthquake level: Downward	Water-level fluctuation (feet): Double amplitude	Remarks
Alabama									
Baldwin, Bal-1	30°24′	87°42′	Sand	134/134	24.6	0.03	0.02	0.05	
Calhoun, Cal-1	33°42′	85°49′	Conasauga Formation	213/124	9.2	1.5	1.6	3.1	
Coffee, Cof-1	31°19′	85°51′	Sand of Lisbon Formation		179	.47	.28	.75	
Colbert, Col-1	34°46′	87°38′	Fort Payne Chert	265	7.5	2.9	3.1	6.0	No aftershocks recorded; 0.3 in. per day, 1:12.
Col-2	34°41′	87°41′	Tuscumbia Limestone	171	10.35(−.30)	1.60	1.85	3.45	0.3 in. per day, 1:1.
Franklin, Fra-1	34°31′	87°44′	Tuscaloosa Group and Bangor Limestone.	210/146	27.87(−.06)			>1	Drum rotated many times.
Jefferson, Jef-1	33°26′	86°53′	Bangor Limestone	140/68	27.1			>10	No aftershocks recorded; 0.3 in. per day, 1:1.
Henry, OW-5	31°37′	85°04′	Clayton Limestone	80?	18.85	.55	.41	.96	First quake ever recorded in well.
Lawrence, Law-2	34°40′	87°21′	Fort Payne Chert	200/55	15.0	2.4	1.5	3.9	Cable thrown off pulley; 0.3 in. per day, 1:12.
Limestone, Ct-2	34°48′	86°58′	do	132/50	11.1	4.4	3.1	7.5	No aftershocks recorded; 1.2 in. per day, 1:12.
Madison, Ct-81	34°38′	86°34′	Tuscumbia Limestone	188/36	22.30(−.10)	.10	.17	.27	
Mad-1	34°44′	86°35′	Fort Payne Chert	140/69	51.65	.07	.05	.12	
N-48	34°45′	86°35′	Tuscumbia Limestone	104/61	25.7	1.32	1.31	2.63	
P-29	34°40′	86°43′	Fort Payne Chert	119/21	22.53(−.04)			>1	Another quake(?) on Mar. 29, but no aftershocks recorded; 1.2 in. per day, 1:1.
Q-174	34°42′	86°35′	Tuscumbia Limestone	65/60	16.3	.11	.15	.26	
Marshall, Mal-2	34°20′	86°19′	Fort Payne Chert	130/124	14.1	1.6	1.5	3.1	
Monroe, Mon-3	31°31′	87°20′	Sand, gravel, and limestone.	128/88	62.28	>.50	>.50	>1	No aftershocks recorded; 0.3 in. per day, 1:1.
St. Clair, St. C-1	33°35′	86°16′	Floyd Shale, Fort Payne Chert, Maury Formation.	209	.2	1.0	1.6	2.6	
Talladega, Tal-2	33°10′	86°15′	Marble	202/68	15.1(−.2)	.7	.9	1.6	
Tuscaloosa, Tus-2	33°11′	87°36′	Gravel	90/72	17.93	41	.27	.68	
Arizona									
Maricopa, (C-1-4) 6bba	33°23′	112°42′	Alluvium	1,694	83.86(−.24)	0.20	0.22	0.42	
Pima, (D-15-11) 5ccc	32°09′	111°15′	do	712	324.65	.36	.36	.72	
Yuma, (6S/23E-32R1)	33°31′	114°44′	Sand, gravel, and silt	560	88.48(−.12)	.07	.25	.32	0.3 in. per day, 1:2.
(B-2-9) 7abb	33°32′	113°13′	Alluvium	1,692	297.35(−.51)	.00	.51	.51	No rise; drop in level only.
(B-6-21) 20ddd	33°50′	114°26′	Sand, silt, and gravel	584/120	11.70	.28	.25	.53	0.3 in. per day, 1:1.
(C-4-6) 18dad	33°03′	112°53′	Alluvium	600	35.68(+.08)			>1	No aftershocks recorded.
(C-4-10) 22abb	33°04′	113°17′	do	274	131.45(−.035)	.102	.135	.237	0.3 in. per day, 1:1.
(C-9-22) 4dbc2	32°26′	114°30′	Sand, gravel, and silt	240				1.14	Clock stopped 3 days before quake; 0.3 in. per day, 1:2.
(C-9-25) 35bab	32°36′	114°48′	do	1,190	17.14	.13	.17	.30	0.3 in. per day, 1:2.
(C-10-24) 15cdd	32°33′	114°43′	do	202				.73	Clock stopped 5 days before quake; 0.3 in. per day, 1:2.
(C-10-25) 31bbb	32°31′	114°40′	Sand and gravel	286	80.31	.10	.13	.23	0.3 in. per day, 1:1.
(C-11-24) 23bcb	32°27′	114°42′	Silt, sand, and gravel	1,038	77.98			>1	Aftershocks recorded (see table 6); 0.3 in. per day 1:1.
Arkansas									
Craighead, 13N-2E-35daa1	35°42′	90°50′	Quaternary sand	120	55.97	0.72	0.77	1.49	No aftershocks recorded; 2.4 in. per day, 1:6.
Dallas, 10S-13W-34aca	33°48′	92°25′	Sparta Sand	888/836	114.10	1.70	1.60	3.30	Do.
Desha, 11S-2W-3cca1	33°46′	91°17′	Cockfield Formation	754	21.86			>1	No aftershocks recorded; 2.4 in. per day, 1:1.2.
Drew, 15S-4W-12dda1	33°24′	91°28′	Sparta Sand	760	32.32			>1	Do.
Lincoln, 7S-5W-17ccc1	34°06′	91°37′	Quaternary sand	120/110	17.56	.95	1.15	2.10	No aftershocks recorded; 2.4 in. per day, 1:6.

TABLE 7.—*Hydroseisms in wells in the United States caused by the Alaska earthquake*—Continued

County, well	Latitude, N.	Longitude, W.	Water-bearing formation	First number, depth of well; second, depth of casing to screen, perforated casing, or open hole (feet)	Depth to water (feet)	Water-level fluctuation (feet): From preearthquake level: Upward	Water-level fluctuation (feet): From preearthquake level: Downward	Water-level fluctuation (feet): Double amplitude	Remarks
California									
Fresno, 15S/16E-20R1	36°36′	120°14′	Alluvium: upper aquifer zone.	1,250/490	71.10	0.71	0.60	1.31	
17S/17E-21N2	36°26′	120°08′	Alluvium: upper and lower aquifer zones.	1,005/404	313.75	.07	.07	.14	
19S/17E-35N1	36°13½′	120°26′	Alluvium	2,030/608	494.08(−.09)	.07	.24	.31	
Imperial, 8 (14S/11E-32R)	32°54′	115°52′	Alluvial silt, sand, and gravel.	560	120.02	.12	.12	.24	0.3 in. per day, 1:1.
11 (15S/18E-15M)	32°35′	115°05′	do	383	25.30(−.21)	.03	.27	.30	Took 2 weeks for water level to recover to stage indicated by prequake trend.
12 (16S/19E-11D)	32°30′	114°59′	Deltaic alluvial deposits	630	13.04	.46	.44	.90	0.3 in. per day, 1:2.
2 (16S/19E-32G1)	32°28′	115°01½′	Alluvium	252	34.00	.08	.12	.20	Water-level trend reversed coincidentally at time of quake; 0.3 in. per day, 1:2.
Kern, 25S/26E-1A2	35°47′	119°07′	do	875/200	352.56	.07	.04	.11	
32S/28E-20Q1	35°07′	118°59′		950	212.10(−.50)	.03	.64	.67	
Los Angeles, 11N/9W-13L1	35°03′	117°47′	Tertiary basalt	462	161.5	.38	.37	.75	0.3 in. per day, 1:1.
8N/10W-8R3	34°48′	117°57′	Alluvium	230	?	.075	.075	.15	
6N/10W-20P1	34°35′	117°58′	do	260	232.57	.09	.08	.17	2.4 in. per day, 1:6.
1S/9W-3B1	34°07′	117°49′	do	408	103.92	.06	.02	.08	1.0 in. per day, 1:1.
2S/11W-5L1	34°01′	118°03′	do	101	20.50(−.10)	.20	.22	.42	1.0 in. per day, 1:5.
2S/12W-10Q2	34°00′	118°07′		552	109.30(−.06)	.50	.42	.92	Do.
Orange, 3S/9W-33Q2	33°52′	117°50′	Alluvium	135	218.48	.08	.07	.15	2.3 in. per day, 1:10.
3S/9W-31J4	33°52′	117°51′	Alluvium (La Habra Formation).	400	158.06	.21	.17	.38	
4S/10W-1C2	33°51′	117°53′	Pleistocene sand and gravel.	514	102.05	.31	.24	.55	Do.
4S/9W-30E1	33°48′	117°52′	do	235	64.35	.53	.36	.89	Do.
5S/11W-16D2	33°45′	118°02′	Alluvium	400	(−)2.60	.26	.20	.46	1.2 in. per day, 1:5.
6S/11W-1Q9	33°40′	117°59′	Pleistocene sand and gravel.	168/68	?	.02	.38	.40	
6S/11W-12G1	33°40′	117°59′	do	200	2.73	.05	.63	.68	Pressure recorder; 51° per day, 1:7.
6S/10W-7E2	33°40′	117°58′	do	330/300	?	.22	.12	.34	Pressure records from two depths in adjacent piezometers; 51° per day, 1:12.
6S/10W-7E4	33°40′	117°58′	do	120/90	4.70	.05	.37	.42	
6S/11W-1Q4	33°40′	117°59′	do	170/70		.02	.25	.27	Do.
6S/11W-1Q6	33°40′	117°59′	do	360/300		.02	.21	.23	
6S/11W-1Q3	33°40′	117°59′	do	174/56		.10	.35	.45	Pressure recorder; 51° per day, 1:28.
6S/11W-1Q9	33°40′	117°59′	do	?/68	(+)3.8	.02	.38	.40	Pressure recorder; 51° per day, 1:14.
Riverside, 7S/22E-17P	33°34′	114°43′	Gravel	265	6.00(−.05)	.07	.12	.19	0.3 in. per day, 1:1.
San Bernardino, 11/26E-31C1.	35°00′	114°38′	Alluvium	143	6.50	.60	.64	1.24	0.3 in. per day, 1:2.
Santa Barbara, 6/32-11G3	34°37′	120°14′	do	28/25	7.349	.002	.010	.012	0.3 in. per day, 1:1.
7/35-22N2	34°40′	120°34′	Sandy gravel	194	7.24(−.02)	.18	.31	.49	0.3 in. per day, 1:5.
7/35-28R1	34°39½′	120°33½′	Careaga Sand	551	60.328(−.005)	.017	.018	.035	0.3 in. per day, 1:1.
7/35-33R1	34°38½′	120°34′	Gravel of Careaga Sand	420	112.157(−.004)	.08	.068	.148	Do.
10/33-7R1	34°57′	120°23′	Alluvium	210	113.21	.06	.07	.13	$T=2\times10^5$; S=0.15–0.30; 0.3 in. per day, 1:5.
Santa Clara, 7S/1E-9D2	37°20½′	121°52½′	do	600	135.47	1.07	1.32	2.39	
7S/1E-16C5	37°19½′	121°52′	do	917	164.36(−.15)	.63	1.05	1.68	
Solano, 8N/1W-33A1			do	200/20	94.2	.20	.24	.44	2.4 in. per day, 1:12.
Tulare, 23S/25E-16N3	35°55½′	119°17′	do	430	173.99	.23	.18	.41	
23S/25E-16N4	35°55½′	119°17′	do	250	95.88	.027	.022	.049	
23S/25E-17Q3	35°55½′	119°17½′	do	355	100.19	.32	.36	.68	
Yolo, 8N/1E-17F1			do	200/20	67.23	.54	.43	.97	2.4 in. per day, 1:6.
Colorado									
Prowers, C23-42-13cdab	38°03′	102°06′	Alluvium	48	7.45	0.12	0.15	0.27	2.4 in. per day, 1:6.
Connecticut									
No wells recorded the quake.									
Delaware									
No report received.									
Florida									
Bay, 006-536-423	30°06′	85°36′	Limestone of Floridan aquifer.		40.10	0.40	0.38	0.78	1.2 in. per day, 1:6.
012-550-331	30°12′	85°50′	do		25.60	.75	.82	1.57	1.2 in. per day, 1:12.
012-541-213	30°12′	85°41′	do		6.13	.85	.73	1.58	0.3 in. per day, 1:5.

TABLE 7.—*Hydroseisms in wells in the United States caused by the Alaska earthquake*—Continued

County, well	Latitude, N.	Longitude, W.	Water-bearing formation	First number, depth of well; second, depth of casing to screen, perforated casing, or open hole (feet)	Depth to water (feet)	Water-level fluctuation (feet)			Remarks
						From preearthquake level		Double amplitude	
						Upward	Downward		
Florida—Continued									
Broward, F291	26°00′	80°08′	Limestone of Biscayne aquifer.	107	(+)1.17	2.04	2.47	4.51	0.3 in. per day, 1:2; float hung after quake.
G561	26°05′	80°08′	do		(+).54	.03	.03	.06	0.3 in. per day, 1:5.
G617	26°05′	80°20′	do		(+)3.6	.12	.11	.23	Do.
G820	26°11′	80°09′	do	215	(−).88	2.87	2.89	5.76	Tape thrown off pulley.
G1222	26°18′	80°05′	do		(+)3.34(−.01)	.03	.01	.04	
S329	26°06′	80°12′	do	70	(+).17	1.91	1.91	3.82	1.2 in. per day, 1:6.
Clay, 948-202-8	29°48′	82°02′	do		56.61			>5	1.2 in. per day, 1:6. No aftershocks; water level declined at time of quake and continued as if aquifer was being drained to a level 4 ft lower.
Collier, C131	26°25′	81°16′	Tamiami Formation	54/52	23.98	1.30	1.28	2.58	1.2 in. per day, 1:6.
C380	25°58′	81°15′	Nonartesian	60/9	(+)4.30	.50	.56	1.06	Do.
C381	26°06′	81°41′	do	60/12	(+)5.00(−.39)	.19	.44	.63	Do.
C382	26°10′	81°42′	do	60/12	(+)7.96	.82	.93	1.75	Do.
Columbia, 9	30°	82°	Limestone of Floridan aquifer.	836/680	91.82	.42	.32	.74	1.2 in. per day, 1:12.
Dade, F45	25°49′	80°12′	do		(+)1.60	1.24	1.47	2.71	2.4 in. per day, 1:6.
F179	25°43′	80°20′	do		(+)1.35	1.16	1.32	2.48	0.3 in. per day, 1:6.
F240	25°50′	80°15′	do	53	(+)1.51	1.51	1.66	3.17	0.3 in. per day, 1:5.
F358	25°28′	80°28′	Limestone of Biscayne aquifer.	54	(+).93	0.17	0.15	0.32	
G72	25°57′	80°25′	Oolitic limestone of Biscayne aquifer.	4.6	(+)4.25	.33	.36	.69	0.3 in. per day, 1:5.
G476	25°36′	80°18′	Limestone of Biscayne aquifer.	24/19	(+)1.13	.48	.39	.87	1.2 in. per day, 1:6.
G553	25°39′	80°20′	do	91/36	(+)2.21	1.10	1.19	2.29	Do.
G595	25°42′	80°02′	do	14/11	(−).60	.02	.02	.04	0.3 in. per day, 1:5.
G613	25°24′	80°32′	do	21/18	(+).33	.08	.15	.23	Do.
G614	25°32′	80°26′	do	20/18	(+)2.02(−.01)	.04	.07	.11	0.3 in per day, 1:2.
G617	26°05′	80°20′	do		(+)3.60	.63	.54	1.17	
G618	25°45′	80°36′	do	20/11	(+)6.12(−.01)	.31	.35	.66	1.2 in. per day, 1:6.
G619	25°45′	80°46′	do	13/7	(+)6.64	.36	.42	.78	0.3 in. per day, 1:2.
G620	25°40′	80°46′	do	16/6	(+)4.80	.38	.50	.88	1.2 in. per day, 1:6.
G858	25°39′	80°24′	do		(+)3.08(−.02)	.05	.13	.18	0.3 in. per day, 1:5.
G860	25°37′	80°19′	do		(+)1.38	.09	.10	.19	Do.
G861	25°38′	80°34′	do		(+)3.68(−.03)	.10	.21	.31	Do.
G863	25°33′	80°34′	do		(+)2.45	.06	.08	.14	
G864	25°26′	80°30′	do		(+).74(−.02)	.22	.24	.46	Do.
G968	25°56′	80°26′	do	50	(+)4.70	.19	.18	.37	1.2 in. per day, 1:6.
G973	25°52′	80°24′	do		(+)2.60	.06	.07	.13	Do.
G974	25°51′	80°24′	do	15/10	(+)3.85(−.01)	.20	.00	.20	1.2 in. per day, 1:12.
G975	25°52′	80°27′	do	15/10	(+)5.60(−.02)	.06	.08	.14	Do.
G976	25°49′	80°25′	do	15/10	(+)4.80	.49	.00	.49	Do.
G1183	25°29′	80°23′	do		(+).75	.35	.33	.68	0.3 in. per day, 1:5.
NP44	25°24′	80°42′	do	33	(+).66(+.04)	1.22	.07	1.29	1.2 in. per day, 1:3.
NP46	25°19′	80°47′	do	25	(−).47	.40	.47	.87	Do.
NP57	25°19′	80°31′	do	54/8	(+).07(−.02)	.51	.43	.94	0.3 in. per day, 1:2.
NP62	25°24′	80°45′	do	20	6.13	.13	.14	.27	0.3 in. per day, 1:5.
NP67	25°19′	80°39′	do	20	(+)0.68			>2	0.3 in. per day, 1:2; tape thrown off pulley.
NP72	25°23′	80°42′	do	20	4.56(−.01)	.06	.10	.16	Do.
S18	25°55′	80°46′	do	52	(+)1.98	.35	.23	.58	
S19	25°48′	80°17′	do	95/91	(−).20	2.40	2.89	5.29	No aftershocks recorded; 0.3 in. per day, 1:5.
S68	25°48′	80°17′	do	64/51	(−)1.93(−.04)	1.47	1.07	2.54	1.2 in. per day, 1:6.
S182	25°35′	80°21′	do	51	(+)1.71	.06	.04	.10	Do.
S196	25°30′	80°29′	do	20	(+)1.23(−.02)	.04	.10	.14	
Desoto, 704-147-332	27°04′	81°47′	Limestone of Hawthorn Formation.	460/112	(+)4.91(+.33)	.90	.14	1.04	1.2 in. per day, 1:12.
Duval, 206	30°15′	81°45′	Floridan aquifer	1,700/1,000	14.85	.15	.12	.27	
Gulf, 30 (948-518-1)	29°48′	85°18′	do	563/300	7.18(−.02)	1.50	1.50	3.00	1.2 in. per day, 1:6.
Hardee, 731-145-1	27°31′	81°45′	do	450	25.40(−.40)	.18	.52	.70	1.2 in. per day, 1:12.
734-202-332	27°34′	82°02′	Floridan aquifer (limestone and dolomite).	1,062/81	65.38(−.29)	.81	1.19	2.00	
738-151-223	27°38′	81°51′	do	737/50	43.02	1.60	1.86	3.46	Pen dislodged by quake.
Hillsborough, 801-213-213a	28°01′	82°13′	Limestone of Floridan aquifer.	417/67	1.77	≥1.63	≥1.73	≥3.36	Cable thrown off; lost float and counterweight; 1.2 in per day, 1:6.
803-234-313	28°03′	82°34′	do	1,120/700	(+)1.73			>5	Cable thrown off pulley.
803-238-212	28°03′	82°38′	do	807/710	(+)2.70		.91		Do.
805-235-113	28°05′	82°35′	do	1,200/656	12.53				Do.
805-236-333	28°05′	82°36′	do	1,200/697	(+)4.89				Do.
805-238-100	28°05′	82°38′	do	1,117/605	(+).32				Do.
807-230-133	28°07′	82°30′	do	300/141	?	?	?	4.45	No aftershocks recorded.
807-230-421	28°07′	82°30′	do	1,250/720	17.87			>10	Cable thrown off pulley.
13 (807-230-433).	28°07′	82°30′	do	362/70	17.81	.93	.82	1.75	
809-232-414	28°09′	82°32′	do	375/65	14.85	2.62	2.6E	5.2E	Water level declined 0.2 ft in 3 hrs after quake recorded, then rose 2.15 ft during next 63 hrs. 1.2 in. per day, 1:6.
Lake, 832-154-334	28°32′	81°54′	do	160/63	2.32	1.17	1.13	2.30	
Lee, L-246	26°38′	81°49′	Tamiami Formation	27/19	(+)16.43	.18	.20	.38	1.2 in. per day, 1:6.
L-414	26°38′	81°49′	Hawthorn Formation	94/60	(+)15.23	.60	.60	1.20	1.2 in. per day, 1:12.

TABLE 7.—*Hydroseisms in wells in the United States caused by the Alaska earthquake*—Continued

County, well	Latitude, N.	Longitude, W.	Water-bearing formation	First number, depth of well; second, depth of casing to screen, perforated casing, or open hole (feet)	Depth to water (feet)	Water-level fluctuation (feet): From preearthquake level: Upward	Water-level fluctuation (feet): From preearthquake level: Downward	Water-level fluctuation (feet): Double amplitude	Remarks
Florida—Continued									
Leon, 7(027-416-1)	30°27′	84°16′	Limestone of Floridan aquifer.	314/165	159.31	4.6E	4.57	9.2E	1.2 in. per day, 1:12.
Madison, 18(028-325-1)	30°28′	83°25′	do	322/307	22.25	2.10	2.58	4.68	
Pasco, 13 (815-226-1)	28°15′	82°26′	do	49/43	5.76	.86	.67	1.53	1.2 in. per day, 1:6.
821-217-221	28°21′	82°17′	do	699/205	108.52(−.10)			>5	6 hours after quake recorded, water level began to rise and rose 0.94 ft in 12 hrs.
826-211-214	28°26′	82°11′	do	227/49	16.29(−.04)	1.26	1.02	2.28	
Pinellas, 561 (750-240-1)	27°50′	82°40′	do	188	3.40	.73	.85	1.58	
665 (758-244-4)	27°58′	82°44′	do	299/81	21.10	1.18	2.01	3.19	1.2 in. per day, 1:12.
246 (758-247-1)	27°58′	82°47′	do	208	26.10	1.80	1.70	3.50	1.2 in. per day, 1:6.
667 (759-243-313)	27°59′	82°43′	do	845	54.32	1.09	1.7E	2.8E	
77 (804-245-1)	28°04′	82°45′	do	282	65.58	.27	.26	.53	1.2 in. per day, 1:12.
13 (808-245-1)	28°08′	82°45′	do	141/33	9.48	1.90	1.91	3.81	Do.
Polk, 753-158-311	27°53′	81°58′	do	710/237	26.41(+.06)	3.88	3.70	7.58	Do.
810-144-1	28°10′	81°44′	do	425/102	8.72(−.08)	2.15	1.48	3.63	Water level began to decline after quake recorded and fell 1.7 ft over 17 days. 1.2 in. per day, 1:6.
Sarasota, 9(719-225-1)	27°19′	82°25′	Limestone of Floridan aquifer.	730/101	3.92	.51	2.30	2.81	Upward motion blocked (?). Water level rose 1.7 ft during 5 days after quake recorded; 1.2 in. per day, 1:12.
Seminole, 125(841-122-1)	28°41′	81°22′	do	158/74	38.50	.80	.71	1.51	Water level rose 0.6 ft in 48 hrs after quake; 1.2 in. per day, 1:21.
Sumter, 821-202-3	28°21′	82°02′	do	143/20	4.59(−.04)	.33	.16	.49	Water level began to rise 6 hrs after quake and rose 0.65 ft in 20 hrs; 1.2 in. per day, 1:6.
Taylor, 35 (003-330-1)	30°03′	83°30′	do	245/189	20.2(+.8)	8.5E	8.5	1.7E	Only well in Florida to record aftershocks; for list, see table 6; 1.2 in. per day, 1:24.
36 (003-331-1)	30°03′	83°31′	Sand	35	6.52	1.13	1.41	2.54	
Volusia, 31 (856-105-1)	28°56′	81°05′	Floridan aquifer	113	4.96	.78	.65	1.43	
905-113-3	29°05′	81°13′	do	351/93	.16	2.7E	2.74	5.4E	
909-106-4	29°06′	81°06′	do	220/152	5.74(−.04)	2.7E	2.66	5.4E	Water level rose 0.25 ft in 18 hrs after quake; 1.2 in. per day, 1:6.
910-105-1	29°05′	81°05′	do	234/102	14.90	4.86	4.36	9.22	Water level rose 0.5 ft in 6 hrs after quake; 1.2 in. per day, 1:12.
Georgia									
Chatham, 63 (37Q7)	32°05′	81°06′	Ocala Limestone	525/120	112.50	2.88	3.30	6.18	No aftershocks recorded.
99 (37Q16)	32°04′	81°04′	do	500/260	79.25(−.05)			>10	Do.
143A (36Q20)	32°00′	81°50′	do	386				>2	Do.
317 (38Q2)	32°02′	80°54′	do	354/110	24.10	5.30	4.45	9.75	Do.
382 (36Q8)	32°05′	81°08′	do	413/250	101.34(−.07)			>5	Do.
429 (37Q34)	32°00′	81°05′	do	327	74.72(−.47)			3.50	Do.
Dawson, 12-3	32°20′	84′05′	Crystalline metamorphic rocks.	400/79	22.04			>1	Aftershocks recorded (see table 6); 2.4 in. per day, 1:12.
Dougherty, 133-400-4	31°33′	84°00′	Ocala Limestone	243/206	27.95	3.88	?	7.76E	Aftershocks recorded (see table 6); 2.4 in. per day, 1:6.
135-406-3	31°36′	84°06′	Clayton Formation	760/713	61.25	.20	.15	.35	First quake ever recorded in well.
Effingham, 7 (34R36)	32°09′	81°23′	Ocala Limestone	431/273	17.00(−.02)			>2	
Fulton, 26	33°42′	84°26′	Injection complex	350	13.42	.002	.021	.023	First quake ever recorded in this watertable well.
Glynn, E143	31°10′	81°30′	Ocala Limestone and upper part of Claiborne Group.	950/823	(+)3.0			>5	$T=1.4\times10^6$; $S=2\times10^{-4}$; no aftershocks recorded; 1.2 in. per day, 1:5.
J35	31°08′	81°29′	Ocala Limestone	710/611	(+)12.7	3.3	2.7	6.0	$T=1.6\times10^6$; $S=3\times10^{-4}$. Pressure recorder.
J36	31°07½′	81°29′	Ocala Limestone and upper part of Clairbone Group.	1,007/589	(+)15.3	3.6	3.3	6.9	$T=2.7\times10^6$; $S=4\times10^{-4}$; no aftershocks recorded. Pressure recorder.
J67	31°05′	81°25′	Ocala Limestone	755/550	(+)23.7	3.0	2.6	5.6	$T=10^6$; $S=3\times10^{-4}$; Pressure recorder.
Laurens, 21T1	32°27′	83°04′	do	113	25.04(−.06)	.98	.99	1.97	
Lowndes, 19E2	30°50′	83°17′	Suwannee Limestone	342/200	115.96(+.02)	.36	.16	.52	First quake ever recorded in well.
Miller, 8H2	31°10′	84°44′	Clayton Formation	1,040/776	31.10(+.30)	1.48	.00	1.48	Water level rose 1.48 ft in 20 min, then declined 1.18 ft in 1 hr; 1.2 in. per day, 1:6.
Mitchell, 10G313	31°05′	84°26′	Ocala Limestone		43.00			>5	Aftershocks recorded (see table 6); 1.2 in. per day, 1:6.

TABLE 7.—*Hydroseisms in wells in the United States caused by the Alaska earthquake*—Continued

County, well	Latitude, N.	Longitude, W.	Water-bearing formation	First number, depth of well; second, depth of casing to screen, perforated casing, or open hole (feet)	Depth to water (feet)	Water-level fluctuation (feet): From preearthquake level: Upward	Water-level fluctuation (feet): From preearthquake level: Downward	Water-level fluctuation (feet): Double amplitude	Remarks
Georgia—Continued									
Thomas, 14E15	30°50′	83°58′	Ocala Limestone	548	195.20			>5	Cable thrown off pulley and float stuck.
14E20	30°51′	80°57′	Suwannee Limestone	299/147	223.19(+.04)	1.29	1.26	2.55	First quake ever recorded in well.
15E12	30°47′	83°51′	do	183/136	(+.084)			>1	Do.
Tift, 17K1	31°27′	83°31′	Ocala Limestone	312	123.50(−.40)	.20	.52	.72	1.2 in. per day, 1:6.
Wayne, 30L3	31°37′	81°55′	Tampa and Suwannee Limestones.	594	65.18	1.15	1.22	2.37	T=2.5×10[6]; 2.4 in. per day, 1:6.
Hawaii									
Oahu, 1A	21°16′	157°46′	Basalt of Kolau Volcanic Series.	131/100	8.27			>1	
2	21°17′	157°48′	do	?/100	25.15			>1	
83	21°18′	157°51′	do	474/458	(+)25.84(+.06)			1.85	Aftershocks recorded (see table 6); 1.2 in. per day, 1:1.
286	21°35′	158°11′	Basalt of Wainae Volcanic Series.	447/447	+6.87	0.03	0.05	.08	Tidal efficiency=10 percent.
332	21°35′	158°07′	Basalt of Koolau Volcanic Series.	225/205	+2.98	.28	.32	.60	Do.
333	21°35′	158°06′	do	163/68	9.14	.09	.05	.14	Tidal efficiency=15 percent.
T-24	21°21′	157°53′	do	115/66	21.95(+.10)	.21	.12	.33	2.3 in. per day, 1:1.
T-28	21°35′	158°06′	do	60/39	23.28	.10	.17	.27	Tidal efficiency=4 percent.
T-45	21°22′	157°55′	do	85/59	19.12(+.07)	?	?	.16	2.3 in. per day, 1:1.
T-52	21°24′	157°56′	do	321/170	19.35			>1	Do.
T-57	21°36′	158°06′	Basalt of Koolau Volcanic Series.	33/11	2.03	.75	.83	1.58	Tidal efficiency=15 percent.
T-67	21°23′	157°57′	do	1,308/91	4.17	.2	.03	.05	Tidal efficiency=2 percent.
T-69	21°20′	157°52′	do	283/233	24.55(?)	.31	.33	.64	Chart pulled from drum by pen; 1.2 in. per day, 1:1.
T-75	21°23′	157°56′	do	250/75	18.16(?)			>1	Rising float stuck between counterweight and casing; 1.2 in per day, 1:1.
T-96	21°35′	158°09′	Reef limestone	60/16	7.00	.35	.60	.95	Tidal efficiency=30 percent.
Shaft 4	21°29′	158°01′	Basalt of Koolau Volcanic Series.					Trace	
Shaft 17	21°35′	158°05′	do		237.60	.05	.05	.10	Maui-type shaft, 608 ft. long.
Waibee Tunnel (1,624 ft long; 24 ft saturated and held by dike and bulkhead)	21°27′	157°51′	do					4.60	Pressure change on horizontal discharge line near the bulkhead.
Idaho									
Bingham, 5S-31E-23ab1	42°58′	112°49′	Basalt of Snake River Group.	46	24.70	0.04	0.05	0.09	0.3 in. per day, 1:2.
Blaine; 1S-19E-3cc2	43°21′	114°12′	Clay, silt, sand, and gravel.	51/51	17.97	.81	.75	1.56	Do.
2S-20E-1ac2	43°17′	114°01′	Basalt of Snake River Group and alluvium.	208/208	151.24	.56	.47	1.03	Do.
Butte, 3N-29E-14ad1	43°35′	112°58′	Basalt of Snake River Group.	588	459.02	2.27	1.71	3.98	2.4 in per day, 1:6.
7N-31E-34bd1	43°55′	112°43′	do	320	269.44	.04	.05	.09	
Canyon, 2N-1W-7bb4	43°32′	116°31′	Basalt of Idaho Group	103/96	11.28	.05	.05	.10	
Cassia, 13S-21E-18bb1	42°18′	114°03′	Paleozoic limestone	850/20	430.92	.66	.76	1.42	Aftershocks recorded (see *table 6*); *0.3 in.* per day, 1:2.
Elmore, 1S-4E-10da1	43°21′	115°57′	Sand and gravel of Idaho Group.	525/485	341.68	.04	.06	.10	0.3 in. per day, 1:1.
Gooding, 8S-14E-16bc1	42°44′	114°50′	Basalt of Snake River Group.	53/50	39.55	.02	.02	.04	2.4 in. per day, 1:6.
Jefferson, 5N-32E-36ad1	43°43′	112°38′	do	406/361	330.07	.71	.50	1.21	Do.
7N-36E-22ab4	43°54′	112°07′	do	35/18	7.09	.33	.40	.73	0.3 in. per day, 1:1.
Jerome, 7S-17E-6ac1	42°51′	114°30′	do	345/322	314.53(− 02)	.02	.02	.04	0.3 in. per day, 1:2.
Latah, 39N-4W-7	46°45′	117°	Columbia River Basalt		255.1			>5	Aftershocks recorded (see table 6); 1.2 in. per day, 1:5.
Lincoln, 5S-17E-26ac1	42°58′	114°24′	Basalt of Snake River Group.	255	202.20	.44	.42	.86	0.3 in. per day, 1:2.
Minidoka, 7S-25E-19ba1	42°48′	113°35′	do	284/284	244.38(−.02)	.82	.96	1.78	Do.
8S-23E-2ba1	42°46′	113°44′	do	254/80	208.65	.62	1.14	1.76	Do.
8S-24E-20db1	42°43′	113°40′	do	367/25	154.10	.15	.15	.30	2.4 in. per day, 1:6.
8S-24E-31dc1	42°41′	113°42′	do	213/175	153.53(−.04)	.09	.16	.25	0.3 in. per day, 1:2.
8S-25E-24bd1	42°43′	113°29′	do	180/160	145.13(−.02)	.11	.09	.20	Do.
Power, 5S-33E-35cc1	42°56′	112°34′	Gravel	60	25.29	.04			Float hung on down movement; 0.3 in. per day, 1:1.

TABLE 7.—*Hydroseisms in wells in the United States caused by the Alaska earthquake*—Continued

County, well	Latitude, N.	Longitude, W.	Water-bearing formation	First number, depth of well; second, depth of casing to screen, perforated casing, or open hole (feet)	Depth to water (feet)	Water-level fluctuation (feet): From preearthquake level: Upward	Water-level fluctuation (feet): From preearthquake level: Downward	Water-level fluctuation (feet): Double amplitude	Remarks
Idaho—Continued									
Power, 7S-30E-28bb1	42°47′	112°58′	Basalt of Snake River Group.	288	198.29	0.00	0.12	0.12	0.3 in. per day, 1:2.
Teton, 4N-45E-13ad1	43°40′	113°05′	Alluvium	304	201.46			>5	1.2 in. per day, 1:6.
Twin Falls, 11S-19E-17aa1	42°29′	114°15′	Basalt of Snake River Group.	860	321.92	.22	.28	.50	0.3 in. per day, 1:2.
11S-20E-21dc1	42°27′	114°07′	do	280	69.85	.24	.32	.56	Do.
Illinois [Data furnished by the Illinois Water Survey and the Northern Illinois Gas Co.]									
Champaign, CHM 19N9E-8.7h.	40°07′	88°12′	Glacial sand and gravel	163	113.77	0.03	0.05	0.08	
Cook, COK 39N12E-11.7f	41°53′	87°50′	Cambrian and Ordovician sandstone.	1,640	553.0			>10	
DeKalb, DEK 40N3E-23.8e1.	41°56′	88°51′	do	1,007	130.87(+.51)	.51	.30	.81	
DuPage, DUP 39N11E-24.2g.	41°51′	87°55′	Silurian dolomite	350	40.90	.82	1.32	2.14	
DUP 38N10E-10.7a1.	41°47′	88°05′	do	53	13.08	.01	.00	.01	
DUP 38N10E-27.6h.	41°45′	88°05′	do	114	47.20	.40	.33	.73	
ANL-9	42°	88°	Niagara Dolomite	140/90	96.09(+.03)			>1	1.2 in. per day, 1:1.
ANL-10	42°	88°	do	199	81.12(+.21)	4.30	3.40	7.70	Aftershocks recorded (see table 6); 1.2 in. per day, 1:10.
LaSalle, Wealdon 9	89°	41°	Troy Grove Gas Storage Field.		89.4	.45	.45	.9	Quake recorded at bottom of water level "low"; 1.2 in. per day, 1:10.
Weldon 15	89°	41°	do		90.36	.00	.00	.00	Water level changed trend and rose 1.0 ft in 13 hrs after quake; 1.2 in. per day, 1:10.
Amfahr 3	85°	41°	do		90.37	.8	.8	1.6	1.2 in. per day, 1:10.
Roulston 3	89°	41°	do		80.4				Water level began dropping when quake hit, fell 1.4 ft in 2 hrs, then reversed and rose 3.6 ft in 60 hrs; 1.2 in. per day, 1:10.
Fordyce 2 (or 3?)	89°	41°	Ancona Gas Storage Field.		144.4	.3	.3	.6	1.2 in. per day, 1:10.
Scheuer 2	89°	41°	Garfield Gas Storage Field.		164.7	.7?	2.1?	2.8?	Float hung during quake; 1.2 in. per day, 1:10.
Fehr 2	89°	41°	do		142.4(+.2)	.2	.2	.4	1.2 in. per day, 1:10.
Peoria, PEO 8N8E-6.1e	40°42′	89°37′	Glacial and and gravels	163	69.0	.80	.70	1.50	
PEO 8N8E-16.7g	40°40′	89°36′	do	53	28.82(+.04)	.09	.05	.14	
PEO 8N8E-17.2e2	40°40′	89°36′	do	53	33.13(+.02)	.02	.02	.04	
Tazewell, TAZ 24N5W-3.8a	40°33′	89°39′	do	80	37.25(−.03)	.02	.13	.15	
TAZ 26N4W-31.2g	40°40′	89°36′	do	79	3.28(−.02)	.17	.08	.25	
Will, WIL 37N10E-10.6f1	41°43′	88°04′	Silurian dolomite	93	73.12	.30	.20	.50	
Indiana									
Allen, Al-4	41°08′	84°53′	Limestone	44	30.48	0.32	0.39	0.71	1.2 in. per day, 1:5.
Al-5	41°04′	84°50′	do	100	23.71(+.01)			>1	No aftershocks recorded; 1.2 in. per day, 1:1.
Benton, Be-2	40°31′	87°23′	Gravel	37	12.67	.12	.07	.19	0.3 in. per day, 1:1.
Clinton, Cl-4	40°17′	86°30′	do	230	17.58(+.03)	.09	.02	.11	1.2 in. per day, 1:5.
Jasper, Jp-4	41°03′	87°01′	Limestone	300	4.53(−.10)	.05	.22	.27	0.3 in. per day, 1:5.
Jefferson, Jf-4	38°46′	85°26′	Ordovician rock	75	25.71(−.08)	.06	.08	.14	1.2 in. per day, 1:5.
Madison, Md-8	40°16′	85°50′	Limestone	415	28.90(−.10)	.27	.36	.63	1.2 in. per day, 1:10.
Marion, Ma-31	39°51′	86°01′	Niagara Dolomite	347/210	101.70(+.7)	3.65	4.60	8.25	0.3 in. per day, 1:10.
Ma-32	39°52′	86°08′	do	322/60	9.92(−.14)			>1	Aftershocks recorded (see table 6); 1.2 in. per day, 1:1.
Marshall, Ml-2	41°21′	86°19′	Gravel	127	22.03	.29	.25	.54	0.3 in. per day, 1:5.
Ml-4	41°27′	86°19′	Sand	133	46.24	.03	.03	.06	0.3 in. per day, 1:10.
Miami, Mi-2	40°40′	86°08′	Limestone	165/66	44.28(−.12)	1.78	1.38	3.16	1.2 in. per day, 1:10.
Newton, Ne-3	40°47′	87°27′	Sand and gravel	103	36.57	1.14	.80	1.94	1.2 in. per day, 1:5.
Parke, Pa-3	39°48′	87°22′	do	124	48.55	.04	.04	.08	0.3 in. per day, 1:5.
Porter, Pt-9	41°28′	87°13′	Limestone	379/236	23.14(−1.92)			>1	No aftershocks recorded; 0.3 in. per day, 1:1.
Posey, Py-2	38°07′	87°47′	Pennsylvanian rock	236	11.60	.04	.06	.10	1.2 in. per day, 1:5.
Pulaski, Pu-6(29/4W-4L1)	40°59′	86°53′	Niagara Dolomite	663	15.93(?)			>1	Aftershocks recorded (see table 6); 1.2 in. per day, 1:1.
Ripley, Ri-4	39°14′	85°06′	Sand and gravel	34	3.59	.03	.05	.08	1.2 in. per day, 1:1.
Spencer, 14	37°58′	87°08′	Sand	56/53	8.46	.015	.02	.035	0.3 in. per day, 1:1.
Starke, Sk-2	41°14′	86°37′	Gravel	83	4.04	.21	.19	.40	Do.
Tippecanoe, Tc-7	40°26′	86°55′	Sand and gravel	207	168.99	.17	.12	.29	1.2 in. per day, 1:1.
Vanderburgh, Van-3	37°59′	87°31′	Sand	90	24.00	.035	.04	.075	0.3 in. per day, 1:1.

TABLE 7.—*Hydroseisms in wells in the United States caused by the Alaska earthquake*—Continued

County, well	Latitude, N.	Longitude, W.	Water-bearing formation	First number, depth of well; second, depth of casing to screen, perforated casing, or open hole (feet)	Depth to water (feet)	Water-level fluctuation (feet): From preearthquake level: Upward	Water-level fluctuation (feet): From preearthquake level: Downward	Water-level fluctuation (feet): Double amplitude	Remarks
Iowa									
Des Moines, 69-3-6A1			St. Peter Sandstone	1,205/854	182.75(−1.75)	0.00	1.75	1.75	Water level dropped at time of quake. No other water-level movement; 2.4 in. per day, 4:5.
Lee, 67-4-3J1			Sand and gravel	156	12.00	.1	.1	.2	1.2 in. per day, 1:10.
Linn, 83-7-28H1			Silurian limestone and dolomite.	420/75	67.7(−.1)	.15	.15	.3	2.4 in. per day, 1:12.
Cairo Dome of Natural Gas Pipeline Co. of America:									
Louisa, Jones G-1			Ordovocian shale and Silurian rock.	?/376	149.9	.00	.16	.16	Water-level decline only; 1.2 in. per day, 1:10.
Hutchinson 0-1			Galena Dolomite	?/571	133.1	2.1(+?)	2.6	4.7(+?)	Cable slipped on pulley at time of quake; 1.2 in. per day, 1:10.
Madison, 75-26-23A1			Mississippian limestone	1,058/657	262.45	.55	.55	1.10	2.4 in. per day, 1:3.
Marion, 74-21-11K1				113/76	44.30(−.05)	.025?	.025?	.05?	Recorder made a jerky-type record; 2.4 in. per day, 1:6.
Story, 83-24-2Q1			Sand and gravel	110	53.85	.075	.075	.15	2.4 in. per day, 1:6.
Washington, 77-924A1				110/47	3.57	.11	.10	.21	0.3 in. per day, 1:6.
Keota Reservoir of Natural Gas Pipeline Co. of America:									
Washington, Anderson 1			St. Peter Sandstone	?/1,189	100.23(+.4)	.75	.41	1.16	Float seemingly hung for 7½ hrs after quake; water level then began *to rise* (*1.82 ft in 40 hrs*); 1.2 in. per day, 1:10.
E. V. Green 1.			do	?/1,219	153.9	.18	.18	.36	1.2 in. per day, 1:10.
Flynn G-1			Galena Dolomite	?/814	120.0	.25	.46	.71	Do.
Woodbury, 89-47-22B2			Dakota Sandstone	343	22.65(−.05)	.61	.55	1.16	2.4 in. per day, 1:12.
Kansas									
Kearny, 23-28-11db	38°	101°	Unconsolidated deposits	296	219.53	0.18	0.19	0.37	2.4 in. per day, 1:6.
Kentucky									
Christian, S-1,502.3-196.8	36°51′	87°27′	Ste. Genevieve Limestone	85	14.09	0.06	0.07	0.13	
Edmondson, S-1,901.4-311.9	37°11′	86°05′	do	295	129.10(+.13)	1.0	.8	1.8	No aftershocks recorded; 0.3 in. per day, 1:10.
Elliott, N-2,315.1-210.7	38°04′	87°09′	Rocks of Pennsylvanian age.	70	22.60	.06	.06	.12	0.3 in. per day, 1:5.
Graves, S-1,150.7-208.2	36°52′	88°39′	Sand	106	16.34	.06	.04	.10	Do.
S-1,154.15-139.90	36°40′	88°38′	do	183	88.17	.23	.18	.41	Do.
Jefferson, N-1,540.0-258.6	38°11′	85°51′	Glacial sand and gravel	112	60.37	.09	.09	.18	0.3 in. per day, 1:1.
N-1,566.00-275.35	38°14′	85°45′	Limestone	190	49.46	.141	.165	.306	Do.
N-1,544.7-264.0	38°12′	85°50′	Glacial sand and gravel	117	77.39	.12	.10	.22	
Johnson, S-2,864.6-536.6	37°46′	82°45′	Sandstone and shale of Breathitt Formation.	115	26.96			>1	No aftershocks recorded; 0.3 in. per day, 1:1.
Letcher, S-2,851.7-329.6	37°12′	82°49′	do	180	17.0	.53	.60	1.13	No aftershocks recorded; 0.3 in. per day, 1:10.
S-2,909.1-321.7	37°10′	82°37′	do	146	21.87	.07	.05	.12	
S-2,858.0-299.9	37°06′	82°48′	do	53	11.18	.04	.03	.07	
Livingston, S-1,276.1-259.3	37°01′	88°14′	Warsaw Limestone	205	46.77	.20	.20	.40	
S-1,276.6-347.9	37°15′	88°14′	Fredonia Limestone, Member of Ste. Genevieve Limestone.	365	22.30	.10	.11	.21	
Lyon, S-1,298.8-270.2	37°03′	88°09′	Warsaw Limestone	99	31.84	.10	.10	.20	
Marshall, S-1,246.2-272.0	37°03′	88°20′	Gravel and sand	92	26.03	.01	.01	.02	
McCracken, S-1,119.0-310.2	37°08′	88°46′	do	86	47.65	.30	.26	.56	0.3 in. per day, 1:5.
Ohio, S-31,672.0-396.7	37°25′	86°52′	Tradewater Formation	298	152.46	.01	.02	.03	
Pulaski, S-2,332.3-243,3	36°59′	84°36′	Limestone of Fort Payne Formation.	146	81.08	.09	.04	.13	
Warren, S-1,888.1-265.3	37°03′	86°08′	St. Louis Limestone	94	71.51	.09	.09	.18	Do.
Louisiana									
Acadia, AC-40	30°18′	92°25′	Chicot aquifer	303	53.28(?)	1.07	0.94	2.01	Float hung after fluctuation; 2.4 in. per day, 1:12.
Ascension, An-2	30°14′	90°55′	Older alluvium	590/550	1.64			>2	No aftershocks recorded; pen hung; 0.3 in. per day, 1:2.
Calcasieu, Cu-77	30°14′	93°16′	"500-foot" sand, Chicot aquifer.	512/450	125.55	.20	.20	.40	2.4 in. per day, 1:6.
Cu-445	30°11′	93°19′	do	540/460	114.40	.78	.80	1.58	0.3 in. per day, 1:5.
Cu-446	30°11′	93°19′	"700-foot" sand, Chicot aquifer.	738/658	83.32	.95	1.05	2.00	Do.

TABLE 7.—*Hydroseisms in wells in the United States caused by the Alaska earthquake*—Continued

County, well	Latitude, N.	Longitude, W.	Water-bearing formation	First number, depth of well; second, depth of casing to screen, perforated casing, or open hole (feet)	Depth to water (feet)	Water-level fluctuation (feet): From preearthquake level: Upward	Water-level fluctuation (feet): From preearthquake level: Downward	Water-level fluctuation (feet): Double amplitude	Remarks
Louisiana—Continued									
Calcasieu, Cu-583	30°13′	93°17′	"700-foot" sand, Chicot aquifer.	670/570	170.70(−.05)	0.24	0.24	0.48	2.4 in. per day, 1:6.
East Baton Rouge, EB-78	30°30′	91°11′	"400-foot" sand	423/332	115.34(+.05)	>.33	.29	>.62	2.4 in. per day, 1:6.
EB-90	30°28′	91°09′	"2,000-foot" sand	2,120/2,025	145.22(−.27)	>.23	.34	>.57	2.4 in. per day, 1:6.
EB-123	30°26′	91°10′	"600-foot" sand	729/630	90.26(+.03)	.03	.35	.38	Do.
EB-127	30°26′	91°11′	"400-foot" sand	330/229	29.16	.04	.00	.04	Do.
EB-128	30°26′	91°10′	"800-foot" sand	970/840	102.00(−.14)			>5	No aftershocks recorded; 0.3 in. per day, 1:5.
EB-155	30°29′	91°10′	"400-foot" sand	412/311	103.50(+.06)	.40	.50	.90	2.4 in. per day, 1:6.
EB-293	30°30′	91°11′	"600-foot" sand	600/540	129.50	1.07	1.10	2.17	2.4 in. per day, 1:30.
EB-652	30°32′	91°08′	"1,500-foot" sand	1,345/1,264	64.83	2.77	>1.14	>3.91	2.4 in. per day, 1:6.
East Feliciana, Ef-1	30°52′	91°01′	Quaternary upland	143	7.45(+.008)	.06	.06	.12	2.4 in. per day, 1:1.2.
Iberville, Ib-2	30°17′	91°14′	Alluvium	280/260	5.30			>5	Reversed on both sides of 1:5 chart; 2.4 in. per day, 1:6.
IB-92	30°07′	91°15′	do	200/160	+1.20	1.10	> .20	>1.30	2.4 in. per day, 1:6.
Jackson, Ja-49	32°17′	92°46′	Sparta Sand	570	158.35	.62	1.41	2.03	Record unusual but difficult to interpret because of reversal; 2.4 in. per day, 1:6.
Jefferson, Jf-120	29°59′	90°09′	"700-foot" sand	780/705	78.70	2.24	>1.30	>3.54	2.4 in. per day, 1:6.
Jefferson Davis, JD-485	30°13′	92°59′	Chicot aquifer	250/240	45.50	.10	.75	.85	2.4 in. per day, 1:12.
Morehouse, Mo-5	32°46′	91°55′	Sparta Sand	860	198	1.15	1.70	2.85	2.4 in. per day, 1:30.
Orleans, Or-42	29°57′	90°02′	"700-foot" sand	757/664	106.27(−.08)	3.10	>.20	>3.30	2.4 in. per day, 1:6.
Or-47	30°02′	90°04′	do	610/527	100.10	1.53	1.52	3.05	Do.
St. Charles, SC-9	30°00′	90°24′	do	777	32.13	.14	.12	.26	0.3 in. per day, 1:5.
SC-14	30°00′	90°24′	"400-foot" sand	404/324	69.00	.88	.77	1.65	Do.
St. John The Baptist, SJB-17.	30°03′	90°27′	do	310	31.95(+.07)			>1	Aftershocks recorded (see table 6); 0.3 in. per day, 1:1.
SJB-86	30°04′	90°29′	do	368/324	31.38(+.04)	.20	1.43	1.63	0.3 in. per day, 1:2.
SJB-145	30°02′	90°39′	Pleistocene	320/305	11.74(−.005)			>1	0.3 in. per day, 1:1.
Union, Un-26	32°44′	92°09′	Sparta Sand	745/670	159.07(−.04)			>1	Do.
Vermilion, Ve-6	29°58′	92°08′	Chicot aquifer	214/125	15.50	.68	.58	1.26	2.4 in. per day, 1:6.
Ve-601	29°46′	92°20′	do	249/167	4.20(+.02)	.17	.21	.38	Do.
Vernon, V-104	31°04′	93°13′	Miocene	855′825	206.25	.12	.01	.13	Do.
Washington, Wa-7	30°47′	89°51′	Pliocene(?)	600/525	11.47	.27	.25	.52	Do.
Webster, Wb-27	32°58′	93°27′	Sparta Sand	312/231	111.43	.08	.08	.61	Do.
West Baton Rouge, WBR-5	30°28′	91°12′	"1,200-foot" sand	1,338	93.30	.68	2.20	2.86	0.3 in. per day, 1:5.
WBR-43	30°25′	91°13′	Alluvium	185/170	18.16			>5	No aftershocks recorded; 0.3 in. per day, 1:5.
West Feliciana. WF-57	30°47′	91°23′	Zone 1 Tertiary	351/311	93.22	.23	.44	.67	0.3 in. per day, 1:2.
Maine									
Cumberland, C-26	43°54′	70°01′	Glacial sand and gravel	101/81	32.37	0.08	0.11	0.19	Well drilled to bedrock. Barometric efficiency= 20 percent; 0.3 in. per day, 1:1.
Maryland									
Charles, Ch-Cb7	38°34′	77°12′	Sand of Patapsco Formation.	400/154	68.54	0.07	0.07	0.14	0.3 in per day, 1:5.
Dorchester, Dor-Cd40	38°34′	76°06′	Sand of Piney Point Formation.	401/369	(−.20)	.00	.20	.20	2.4 in. per day, 1:6.
Prince Georges, PG-Cf6	38°57′	76°44′	Sand of Magothy Formation.	207/?	+53.49(−.03)	.10	.14	.24	0.3 in. per day, 1:1.
PG-Fd39	38°44′	76°50′	do	456/436	+39.25	.13	.15	.28	2.4 in. per day, 1:6.
Massachusetts									
Berkshire, Lee-44	42°19′	73°14′	Stockbridge Limestone	49	9.13	0.31	0.31	0.62	0.3 in. per day, 1:2.
Michigan									
Bay, 17N 4E 22-1	43°51′	83°59′	Saginaw Formation	110/60	5.35	0.18	0.18	0.36	
Calhoun, 18 7W 32-3	42°20′	85°09′	Marshall Formation	95/40	25.00(+.1)	1.27	1.01	2.28	0.3 in. per day, 1:5.
2S 8W 2-1	42°19′	85°12′	do	92/45	15.25	.71	.56	1.27	
Clinton, 5N 2W 31-1	42°46′	84°36′	Saginaw Formation	195	61.22	.16	.19	.35	
Delta, 39N 23W 28-3	45°45′	87°09′	Munising Sandstone	530	2.94	1.12	1.10	2.22	
Eaton, 3N 3W 2-1	42°40′	84°38′	Glacial drift	66/66	4.04	.21	.15	.36	
4N 4W 11-1	42°45′	84°45′	Saginaw Formation	350	251	.16	.11	.27	
4N 4W 2-1	42°45′	84°45′	do	376/23	29.77	.005	.01	.015	0.3 in. per day, 1:1.
4N 3W 12-1	42°44′	84°37′	do	381/140	81.88	.42	.46	.88	
Genesee, 7N 7E 17-1	43°00′	83°40′	Saginaw Formation. Well bottoms in old coal mine.	222	25.68			>2	Aftershocks recorded (see table 6); 0.3 in. per day, 1:2.

TABLE 7.—*Hydroseisms in wells in the United States caused by the Alaska earthquake*—Continued

County, well	Latitude, N.	Longitude, W.	Water-bearing formation	First number, depth of well; second, depth of casing to screen, perforated casing, or open hole (feet)	Depth to water (feet)	Water-level fluctuation (feet): From preearthquake level: Upward	Water-level fluctuation (feet): From preearthquake level: Downward	Water-level fluctuation (feet): Double amplitude	Remarks
Michigan—Continued									
Gogebic, 48N 47W 34-2	46°31′	90°09′	Glacial drift	35/35	0.71(+.02)	0.00	1.35	1.35	
48N 47W 34-3	46°31′	90°09′	do	22/22	3.04	.88	.74	1.62	
48N 47W 31-1	46°31′	90°13′	do	115/115	22.40	.60	.58	1.18	
Ingham, 4N 2W 24-1	42°43′	84°29′	Saginaw Formation	453/80	65.10	.92	.82	1.74	0.3 in. per day, 1:10.
4N 1W 27-1	42°42′	84°25′	do	278/77	6.85			>1	0.3 in. per day, 1:1.
4N 1E 21-1	42°43′	84°20′	do	265	21.525	.055	.055	.11	
3N 2W 23-2	42°38′	84°30′	do	268/50	7.33			>1	Do.
2N 1W 5-2	42°35′	84°26′	do	210/37	22.50	.19	.185	.375	
Ionia, 7N 7W 25-1	42°58′	85°05′	Glacial drift	23	16.92	.015	.00	.015	
Jackson, 3S 1W 2-1	42°14′	84°23′	Marshall Formation	221	38.50	1.67	2.06	3.73	0.3 in. per day, 1:10.
3S 1W 10-1	42°13′	84°25′	Saginaw and Marshall Formations.	323/55	31.65	.73	.84	1.57	
3S 1W-11-3	42°14′	84°23′	Glacial drift	36/33	12.00	.04	.04	.08	Do.
Kalamazoo, 2S 11W 20-11	42°17′	85°37′	do	81	17.20	.03	.03	.06	
3S 12W 11-1	42°13′	85°41′	do	248	(+)0.365	.12	.08	.20	0.3 in. per day, 1:1.
Kent, 6N 12W 27-1	42°53′	85°43′	Marshall Formation	265/207	52.65	.40	.40	.80	0.3 in. per day, 1:2.
6N 12W 34-1	42°52′	85°42′	do	300/150	68.21			>5	Aftershocks recorded (see table 6); 0.3 in. per day, 1:5.
6N 9W 3-1	42°56′	85°22′	Glacial drift	70	17.55	.02	.02	.04	
5N 12W 4-7	42°50′	85°44′	do	227/182	8.63	.19	.22	.41	
5N 12W 4-3	42°50′	85°44′	do	86	11.77(−.04)	.43	.35	.78	0.3 in. per day, 1:1.
Livingston, 2N 4E 3-1	42°36′	83°58′	Saginaw Formation	148	12.75	2.27	2.27	4.54	
Mackinac, 42N 2W 7-1	46°03′	84°36′	Manistique Dolomite	102	25.70	2.20	2.60	4.80	
Manistee, 21W 17N 14-1	44°14′	86°20′		212	33.06	.13	.175	.305	Do.
Marquette, 47N 28W 1-1	46°30′	87°45′	Glacial drift	216	19.09(−.01)	.30	.45	.75	
47N 28W 3-1	46°30′	87°47′	do	75				.70	
Oakland, 3N 9E 36-1	42°38′	83°20′	do	134	96.78	.03	.03	.06	
3N 10E 13-2	42°40′	83°13′	do	183/173	86.80	1.05	1.05	2.10	
3N 10E 31-1	42°38′	83°12′	do	173/153	78.85	.35	.45	.80	0.3 in. per day, 1:10.
3N 10E 32-1	42°38′	83°11′	do	160/7	79.90	.80	1.10	1.90	Do.
3N 11E 4-1	42°42′	83°10′	do	73	28.60	.25	.25	.50	
Presque Isle, 33N 6E 15-1	45°15′	83°41′	Traverse Group	31/22	6.90	.45	.45	.90	
Schoolcraft, 47N 16W 30-1	46°26′	86°21′	Prairie du Chien Group	57/40	15.45	.07	.08	.15	
Van Buren, 4S 16W 22-1	42°06′	86°09′	Glacial drift	134/119	27.46	.005	.005	.01	
Washtenaw, 3S 6E 16-3	42°13′	83°44′	do	55/36	12.50	.35	.35	.70	
3S 7E 5-1	42°15′	83°38′	do	69	3.34	.06	.05	.11	
3S 7E 9-3	42°14′	83°38′	do	94/90	66.34	.05	.07	.12	
3S 7E 24-6	42°12′	83°34′	do	75/70	33.51	.31	.86	1.17	
Wayne, 1S 8E 17-1	42°24′	83°31′	do	114	53.90	.58	.59	1.17	
Wexford, 21N 9W 4-1	44°22′	85°24′	do	277	25.995	.18	.105	.285	0.3 in. per day, 1:1.
Minnesota									
Dodge, 107.17.34dcc1	44°01′	92°50′	St. Peter Sandstone	500/118	88.95	>0.5	>0.5	>1	Drum rotated more than once but no aftershocks recorded.
Grant, 129.42.9ccc1	45°59′	95°58′	Glacial drift	214/200	77.02	.06	.05	.11	
Hennepin, 29.23.19cdd1	44°58′	93°13′	Hinckley Sandstone	1,016/925	180.13	.39	.12	.51	
117.21.16cca	44°56′	93°21′	Jordan Sandstone	421/280	76.5(−.2)	.5	.5	1	
117.22.5abd2	44°58′	93°29′	Sandstone and limestone	483/201	45.7	>1	>1	>2	Drum rotated more than once; water level declined 2 ft in 40 hrs after quake.
117.22.8dbd2	44°57′	93°29′	Jordan Sandstone	503/228	22.26	>.79	>.44	≥1.23(?)	Do.
117.23.11bbd1	44°57′	93°33′	do	437/270	18.48(+.32)	>1	>1	>2	Drum rotated more than once.
117.23.34daa2	44°53′	93°33′	Sandstone and limestone	468/199	58.30	>1	>1	>2	Do.
Itasca, 55.25.17acd1	47°14′	93°32′	Glacial sand and gravel	147/143	32.80	.52	.39	.91	
Mower, 102.18.2bdd1	43°40′	92°58′	Limestone	244	19.05(+2.35)	2.35	2.05	4.40	No aftershocks recorded.
Nobles, 102.40.27ccd1	43°36′	95°37′	Glacial sand and gravel	34/18	11.33	.09	.09	.18	
St. Louis, 57.20.5dad1	47°26′	92°53′	Biwabik Iron-formation	430/315	65.68(+.40)	.62	.00	.62	
57.20.31dbc1	47°22′	92°55′	Glacial outwash sand and gravel.	92/82	11.26	.02	.02	.04	
58.18.12ccc1	47°31′	92°34′	do	97/76	17.24(−.05)	>.26	>.36	>.62	Ink flowed too slowly to record fluctuation.
Yellow Medicine, 114.45.4dcd1.	44°42′	96°17′	do	62/44	8.71	.19	.20	.39	
Mississippi									
Forrest	31°19′	89°15′	Terrace sand and gravel	108/88	12.90	0.7	0.6	1.3	On bank of Leaf River; 1.2 in. per day, 1:1.
	31°11′	89°11′	Hattiesburg Formation	416/392	127.89(−.03)	.16	.13	.29	
Grenada	33°50′	89°47′	Tallahatta Formation	282/227	8.66	.20	.20	.40	
Lamar, HT16	31°09′	89°33′	Pascagoula and Hattiesburg Formations.	889/838	101.50	.5	.5	1	Riovi syncline, Tatum salt dome.
HT2A	31°07′	89°34′	Hattiesburg Formation	1,080/935	132.53	.5	.5	1	Do.
HT5	31°08′	89°34′	Catahoula(?) Sandstone	680/579	104.24	.5	.5	1	On top of Tatum salt dome.
E7	31°08′	89°34′	Limestone caprock of salt dome.	1,386/945	94.10(+.25)	2.25	.09	2.34	Do.
E9	31°08′	89°34′	do	1,450	84.96(+.1)	.60	.70	1.30	Do.
Lowndes	33°23′	88°26′	Sand of Gordo Formation.	500/400	.85(−.06)	1.15	1.15	2.30	

TABLE 7.—*Hydroseisms in wells in the United States caused by the Alaska earthquake*—Continued

County, well	Latitude, N.	Longitude, W.	Water-bearing formation	First number, depth of well; second, depth of casing to screen, perforated casing, or open hole (feet)	Depth to water (feet)	Water-level fluctuation (feet): From preearthquake level: Upward	Water-level fluctuation (feet): From preearthquake level: Downward	Water-level fluctuation (feet): Double amplitude	Remarks
Mississippi—Continued									
Rankin	32°18′	89°47′	Cockfield Formation	594/565	104.07	.20	.20	.40	
Washington	33°02′	90°59′	Alluvium of Mississippi Valley.	105/80	11.59	.18	.22	.40	
Missouri									
[Data furnished by the Missouri Geological Survey and Water Resources]									
Barton, 32N/30W-30cd	37°29′	94°16′	Dolomite	971/553	223.83(+.4)	>2.85	>2.15	>5	Aftershocks recorded (see table 6); 1.2 in. per day, 1:6.
Bollinger, 28N/9E-32dca	37°03′	90°05′	Quaternary alluvium	115/70	7.15	.02	.04	.06	
Butler, 26N/5E-34ca	36°52′	90°31′	Gasconade Dolomite	631	139.27(+.65)	2.45	>.23	>2.68	1.2 in. per day, 1:6.
Callaway, 44N/11W-15bab	38°36′	92°10′	Quaternary sand	99/91	32.07	.1		.1	
Cape Girardeau, 29N/12E-8db.	37°11′	89°45′	Quaternary alluvium	75/70	18.1	.02	.20	.22	
Dunklin, 22N/10E-34cdc	36°30′	89°58′	Wilcox(?) Group	130/104	14.9	.55	>1.1	>1.65	
Franklin, 42N/1W-26dd	38°21′	90°59′	Dolomite	255	67.8	.05	.12	.17	
44N/1W-27cbbc	38°32′	91°01′	do	1,360	75.0	>1.0	2.9	>3.9	Aftershocks recorded (see table6); 1.2in. per day, 1.6.
Greene, 29N/22W-13bcc	37°13′	93°17′	do	1,346	393.9	>9.9	>.1	>10	Between Mar. 28 and June 2, water level rose 50 ft; 1.2 in. per day, 1:12.
Howell, 24N/8W-21ca	36°44′	91°51′	do	1,305/800	308.45	6.45	>1.55	>8	
26N/10W-16	36°56′	92°03′	do	780/650	212.5	1.55	.5	2.05	1.2 in. per day, 1:6.
Howell (West Plains), 32N/30W-31.	36°45′	91°45′	do		148.4(+.24)	6.5	>1.6	>8.1	1.2 in. per day, 1:12.
Jasper, 27N/32W-1bac				1,747/375	42.7	1.95	.85	2.80	
McDonald, 21N/33W-22aa	36°32′	94°29′	Dolomite	850/99	86.5	2.2	2.9	5.1	
23N/30W-18aad	36°40′	94°14′	Limestone	346/44	123.35	.1	.05	.15	
Madison, 33N/7E-20bcd	37°32′	90°18′	Dolomite, sandstone, and arkose.	590/187	103.55		1.10	>1.10	Water level rose 5.55 ft in 40 hrs after quake and 1.65 ft more in next 98 hrs.
Marion, 58N/5W-10ab	39°51′	91°26′	Alluvium	129/81	23.98	.05	.12	.17	
Mississippi, 25N/16E-29ccb	36°47′	89°21′	do	130/113	8.15	.06	.06	.12	
Pemiscot, 17N/11E-36ab	36°04′	89°49′	do	195/126	15.9	.15	.15	.30	
Perry, 34N/8E-34c	37°36′	90°08′			177.3(+.60)	1.65	1.05	2.70	
Phelps, 34N/9W-18	37°39′	91°58′	Dolomite	450/273	189.0(−.3)	2.3	>1.5	>3.8	1.2 in. per day, 1:6.
Polk, 33N/21W-5adc	37°37′	93°15′	do	200/42	67.66(−1.1)				Water level fell 1.1 ft in 1½ hrs after quake.
Ripley, 22N/4E-3dd	36°35′	90°37′	Alluvium and dolomite	65/61	13.65	.04	.04	.08	
St. Clair, 38N/26W-22adc	38°02′	93°46′	Dolomite	875/20	109.4	.15	.15	.30	
St. Louis, 44N/3E-34cdba	38°30′	90°40′	St. Peter(?) Sandstone	150	77.55	.05	.05	.10	
47N/8E-18	38°48′	90°09′	Quaternary alluvium	125/100	35.18	.05	.10	.15	
Scott, 26N/14E-21bab	36°53′	89°33′	do	145/142	8.25	.25	.25	.50	
Shannon			Upper aquifer		(−.55)			>5.00	
			Lower aquifer		(−.55)			2.95	
Taney, 24N/18W-13d	36°45′	92°53′	Dolomite	598/206	250.67(+1.17)	1.17	.1	1.27	
Texas, 30N/11W-17dda	37°18′	92°10′	do	481/50	272.57	.13	.13	.26	
Montana									
Gallatin, A1-4-25dc	45°48′	111°10′	Alluvium	101	16.49(+.02)			>1	Aftershocks recorded (see table 6); 0.3 in. per day, 1:1.
Flathead, 29-20-29bd	48°14′	114°11′	Valley fill	152	26.52	0.385	0.22	0.605	0.3 in. per day, 1:1.
Missoula, 13-19-8cb	46°54′	114°03′	do	112	51.47	1.43	1.45	2.88	No aftershocks recorded; 2.4 in. per day, 1:6.
Nebraska									
Adams, 7-10-23ab	40°34′	98°24′	Pleistocene sand and gravel.	155	109	0.10	0.10	0.20	
Hamilton, 10-6-26bc	40°48′	97°58′	do	130	87.5(−.05)	.13	.13	.26	
Kearney, 5-15-3ba	40°26′	99°00′	do	122	96	.09	.03	.12	
Lancaster, A10-6-36cdd	40°47′	96°41′	Dakota Sandstone	170	62.60	2.05	2.05	4.10	No aftershocks recorded.
Merrick, 12-8-36bc	40°58′	98°11′	Pleistocene sand and gravel.	8	3.45	.025	.025	.05	
Polk, 14-2-21db	41°10′	97°33′		180	81.45				Water level declined 0.20 ft 8 hrs after quake.
Saline, A8-3-19ad	40°38′	97°07′	Pleistocene sand and gravel.	151	97.37(−0.07)	.06	.14	.20	
Thayer, 4-1-9bac	40°20′	97°26′	do	95	89	.87	.00	.87	No fall below prequake level.
York, 9-4-6dd	40°53′	97°35′	do	102	86	1.18	1.16	2.34	

TABLE 7.—*Hydroseisms in wells in the United States caused by the Alaska earthquake*—Continued

County, well	Latitude, N.	Longitude, W.	Water-bearing formation	First number, depth of well; second, depth of casing to screen, perforated casing, or open hole (feet)	Depth to water (feet)	Water-level fluctuation (feet): From preearthquake level: Upward	Water-level fluctuation (feet): From preearthquake level: Downward	Water-level fluctuation (feet): Double amplitude	Remarks
Nevada									
Clark, S 19/53-32aaa1	36°15′	116°02′	Alluvium	300	27.11(+.004)	0.015	0.01	0.025	0.3 in. per day, 1:1.
S 19/60-9bcc1	36°19′	115°19′	do	830/140	106.02(−.14)			>1	Aftershocks recorded (see table 6); 1.2 in. per day, 1:1.
S 21/54-10aac1	36°21′	115°53′	do	800/472	71.69(−.02)	.51	1.22	1.73	Pen moved faster than ink could flow. 0.3 in. per day, 1:2.
S 21/54-28bd1	36°06′	115°55′	do	140	22.72	.03	.03	.06	0.3 in. per day, 1:1.
S 22/61-4bcc1	36°04′	115°10′	do	355	109.85(−.28)	.18	.29	.47	1.2 in. per day, 1:1.
New Hampshire									
No wells recorded the quake.									
New Jersey									
Atlantic, Pleasantville	39°24′	74°30′	Kirkwood Formation (800-ft sand).	680	(−)34.39	0.06	0.03	0.09	
Amatol	39°35′	74°41′	Cohansey(?) Sand	137	5.11	.03	.03	.06	
Wharton 2-G	39°40′	74°40′	Cohansey Sand	76	(+)92.95	.09	.09	.18	
Jobs Point	39°18′	74°37′	Kirkwood Formation	680/670	(−)28.74(−.04)	.24	.09	.33	
Oceanville	39°27′	74°27′	do	570/560	(−)21.11(−.03)	.01	.12	.13	
Burlington, Medford	39°55′	74°50′	Englishtown Formation	265/253	(+)45.84(−.01)	.10	.13	.23	
----------	39°55′	74°50′	Raritan Formation	410/400	(−)14.90(−.02)	.08	.10	.18	
Lebanon 18-V	39°54′	74°28′	Cohansey Sand	99	(+)128.85(−.03)	.06	.12	.18	
Sawmill 1	39°52′	74°31′	do	79	(+)114.92(−.02)	.01	.05	.06	
Sawmill 2	39°52′	74°31′	do	81/76	10.80	.03	.04	.07	
Camden, Egbert	39°52′	75°04′	Raritan and Magothy Formations.	454	(−)39.63	.04	.13	.17	
Elm Tree 3	39°49′	74°56′	Englishtown Formation	717/706	(−)25.92(−.07)	.01	.14	.15	
Esterbrook	39°56′	75°07′	Raritan Formation	300	(−)5.04(−.18)	.26	.53	.79	
Oaklyn	39°53′	75°04′	Raritan and Magothy Formations.	112	(−)34.20	.11	.11	.22	
N.Y. Ship	39°54′	75°07′	Raritan Formation	104	(−)21.47(+.02)	.10	.06	.16	
New Brooklyn 1	39°42′	74°56′	do	1,495	(−)12.33(−.04)	.06	.11	.17	
New Brooklyn 2	39°42′	74°56′	Raritan and Magothy Formations.	848	(−)24.23(−.01)	.06	.01	.07	
Cape May, Canal	38°57′	74°55′	Cohansey Sand	252/242	(−)13.39	.06	.05	.11	
County Park	39°06′	74°48′	Cohansey Sand	232/217	(+)6.25(−.01)	.08	.12	.20	
Higbee Beach	38°57′	74°57′	do	252/242	(−)11.80	.20	.21	.41	
Essex, East Orange W.W.	40°44′	74°20′	Wisconsin terminal moraine.	64	(+)131.31(−.10)	.00	.10	.10	
Ballantine	40°43′	74°08′	Brunswick Shale	875	(−)80.14	.13	.07	.20	
Gloucester, Shell 5	39°49′	75°13′	Raritan and Magothy Formations.	327	31.63	.13	.13	.26	
Shell 7	39°49′	75°13′	do	322	31.18	.14	.09	.23	
Texaco 3	39°52′	75°09′	do	298/225	−)48.42	.22	.14	.36	
Hercules (Gibbstown)	39°49′	75°16′	Raritan Formation	100	(−)2.68	:07	.06	.13	
Middlesex, Forsgate 3	40°20′	74°27′	Raritan and Magothy Formations.	138/128	(+)70.65	.05	.08	.13	
Duhernal 1	40°24′	74°21′	Old Bridge Sand Member of Raritan Formation.	67	(+)4.57	.015	.005	.02	
Morris, International Pipe	40°52′	74°26′	Wisconsin drift	155	(+)295.42(+.04)	1.30	1.57	2.87	
Randolph Township	39°40′	74°33′	Byram Granite Gneiss	218	5.32	.18	.23	.41	
Whippany	40°49′	74°23′	Wisconsin glacial outwash	170	(+)174.18	.11	.14	.25	
Madison 4	40°45′	74°23′	Wisconsin drift	100	(+)173.45(+.10)	.24	.33	.57	
Ocean, Colliers Mills 1	40°04′	74°27′	Englishtown Formation	427/417	54.50	.02	.03	.05	
Colliers Mills 3	40°04′	74°27′	Mount Laurel Sand	267/257	18.68(−.01)	.01	.04	.05	
Garden State 2	39°47′	74°14′	Kirkwood Formation	317	(+)37.18	.02	.00	.02	
Union, Hillside 4	40°41′	74°13′	Brunswick Shale	400	(+)24.40	2.14	2.23	4.37	Only one distinct aftershock recorded (see table 6); 1.2 in. per day, 1:5.
White 2	40°40′	74°16′	do	250	(+)56.16	1.13	1.21	2.34	
White 4	40°40′	74°16′	do	350	(+)51.18(+.05)	.15	.10	.25	
County Park	40°41′	74°17′	do	290	(+)59.03	.24	.22	.46	
Hatfield	40°37′	74°16′	do	?	(+)17.37(+.08)	.40	.49	.89	
New Mexico									
Chaves, Berrendo (10.24.9.333)	33°27′	104°31′	San Andres Limestone	258	56.15	0.95	0.99	1.94	2.4 in. per day, 1:6.
Berrendo-Smith (10.24.21.212)	33°26′	104°31′	do	324	53.55	>3.5	>1.5	>5	Pen moved faster than ink could flow. No aftershocks recorded; 2.4 in. per day, 1:6.
11.23.3.342	33°22′	104°36′	do	595	188	.38	>.14	.76E	2.4 in. per day, 1:1.2.
Eddy, 18.26.6.442	32°46′	104°24′	do	1,008	148.03	>3	>2	>5	Aftershocks(?).

TABLE 7.—*Hydroseisms in wells in the United States caused by the Alaska earthquake*—Continued

County, well	Latitude, N.	Longitude, W.	Water-bearing formation	First number, depth of well; second, depth of casing to screen, perforated casing, or open hole (feet)	Depth to water (feet)	Water-level fluctuation (feet): From preearthquake level: Upward	Water-level fluctuation (feet): From preearthquake level: Downward	Water-level fluctuation (feet): Double amplitude	Remarks
New Mexico—Continued									
Eddy, 22.26.36.111a	32°21′	104°15′	Alluvium	260	?(+.07?)	0.05	0.048 or .07	0.10(+?)	Entire fluctuation was above prequake water level; 1.2 in. per day, 1:1.
21.26.36.221	32°26′	104°14′	Capitan Limestone	327	21.61			>1	Chart pulled from drum by pen. 1.2 in. per day, 1:1.
Grant, 18.15.11.323	32°45′	108°22′	Conglomerate	580		.02	.02	.04	2.4 in. per day, 1:12.
Lea, 17.33.13.341	32°49′	103°37′	Ogallala Formation	252	158.87	.033	.04	.073	A water-table well; 1.2 in. per day, 1:1.
16.36.5 Lotz	32°57′	103°22′	do	97	58.13	.005	.010	.015	1.8 in. per day, 1:2.4.
Roosevelt, 1N.33.36.400C	34°15′	103°25′	Valley fill	43	18.52	.03	?	?	A water-table well in which water level rose 0.03 ft then declined to normal over 4 hrs time; 1.8 in. per day, 1:2.4.
1.34.25.211	34°12′	103°19′	do	101	73.0(+.01)	.02	.02	.04	1.8 in. per day, 1:2.4.
Sierra, Hot Springs 6	33°07′	107°15′	Magdalena Group	105	.10(−.38)			>1	Aftershocks recorded (see table 6); 1.8 in. per day, 1:10.
New York									
Chautauqua, Cu-10(208-912-16)	42°08′	79°12′	Sand and gravel	232	30.06	1.20	0.90	2.10	One aftershock recorded (see table 6); 1.2 in. per day, 1:10.
Erie, 255-812-2	42°	78°	Glacial sand and gravel	81/81	4.93(−.03)	.00	.04	.04	Water level rose 0.23 ft in 22 hrs after quake; 0.3 in. per day, 1:1.
Genesee, 259-809-3	43°	78°	do	54/51	21.04	.30	.38	.68	0.3 in. per day, 1:1.
Nassau, N-7161	40°39′	73°39′	Magothy Formation	671/661	(+)5.75	.1	.1	.2	
N-3867	40°30′	73°43′	do	517/506	(+)3.35	.48	.55	1.03	
Niagara, 306-902-1	43°06′	79°02′	Lockport Dolomite	36	18.35	.02	.02	.04	0.3 in. per day, 1:5.
Onondaga, 253-614-1	42°53′	76°14′	Hamilton Group	160/43	41.5	?	?	1.70	
Rensselaer, 235-342-10	42°35′	73°42′	Coarse sand and gravel	96	27.79	.21	.22	.43	0.3 in. per day, 1:1.
St. Lawrence, 452-459-2	44°52′	74°59′	Beekmantown Dolomite	180/54	13.12	.22	.24	.46	Pen quit recording during quake; 0.3 in. per day, 1:1.
North Carolina									
Chowan, CHO-2	36°14′	76°39′		320	9.21	0.17	0.00	0.17	2.4 in. per day, 1:6. Water level rose quickly 0.17 ft then declined to prequake level in 20 min.
New Hanover-Kure Beach	34°00′	77°55′	Castle Hayne Limestone	158	17.30	.92	.93	1.85	2.4 in. per day, 1:6.
Onslow	34°45′	77°25′		240	9.07	1.00	.78	1.78	Do.
North Dakota									
Burleigh, 138-77-22aad			Glaciofluvial sand and gravel.	126/118	12			1.9	? in. per day, 1:12.
138-8-15cdd			do	168/140	36			.32	? in. per day, 1:6.
Ward Test Hole 2216, 155-82-19dbd.	48°	101°30′	do	107	40.80	0.60	0.29	.89	2.4 in. per day, 1:6.
Ohio									
Auglaize, Au-2	40°32′	84°23′	Gravel	100	6.68(−.08)	0.08	0.13	0.21	
Belmont	40°02′	80°44′	Alluvial sand and gravel	59	24.37	.14	.13	.27	Coda lasted 40 min. First detectable motion 15 min before L max; 9.6 in. per day, 1:1.
Carroll, C-1	40°37′	81°05′	Sandstone	60	23.51(−.07)	.16	.16	.32	
Champaign, Ch-2	40°06′	83°45′	Gravel	29	19.63	.05	.05	.10	
Clark, Cl-1	39°58′	83°43′	Glacial outwash gravel	57	4.6	.52	.68	1.20	0.3 in. per day, 1:10.
Cl-2	39°55′	83°51′	Gravel	74	5.80	.20	.20	.40	0.3 in. per day, 1:5.
Cl-8	39°58′	83°48′	Limestone	75	21.90(+.06)	.39	.33	.72	
Delaware, Dl-3	40°21′	83°04′	Columbus Limestone	135	29.92(+.48)	.79(?)	.77	1.56?	Do.
Fulton, Fn-1	41°35′	84°00′	Gravel	130	61.11	.08	.04	.12	
Geauga, Ge-3a	41°25′	81°22′	Sandstone of Cuyahoga Formation.	120	40.28(+.08)	.50	.20	.70	
Hamilton, H-1	39°11′	84°47′	Gravel	124	25.36	.06	.06	.12	
H-2	39°17′	84°39′	do	89	12.50	.36	.36	.72	Do.
H-9	39°13′	84°27′	do	168	104.10	.22	.19	.41	Do.
H-10	39°12′	84°28′	do	170	92.35	.30	.27	.57	0.3 in. per day, 1:10.
Holmes, Ho-1	40°35′	81°54′	Sandstone of Logan Formation.	43	3.58	.58	.46	1.04	0.3 in. per day, 1:2.
Lucas, Lu-1	41°37′	83°36′	Limestone	250	95.26	.10	.10	.20	
Marion, Mn-1	40°34′	83°23′	do	100	9.05	.25	.28	.53	0.3 in. per day, 1:5.
Miami, Mi-1	40°02′	84°12′	Gravel	49	9.04	.13	.12	.25	

TABLE 7.—*Hydroseisms in wells in the United States caused by the Alaska earthquake*—Continued

County, well	Latitude, N.	Longitude, W.	Water-bearing formation	First number, depth of well; second, depth of casing to screen, perforated casing, or open hole (feet)	Depth to water (feet)	Water-level fluctuation (feet): From preearthquake level			Remarks
						Upward	Downward	Double amplitude	
Ohio—Continued									
Montgomery, Mt-6	39°45′	84°11′	Gravel	60	36.05	0.22	0.23	0.45	0.3 in. per day, 1:10.
Mt-49	39°40′	84 16′	do	220	18.69	.04	.03	.07	
Pickaway, Pk-2	39°42′	82°57′	Gravel	87	18.2			.62	0.3 in. per day, 1:5.
Portage, Po-3	41°10′	81°02′	Sandstone	172	25.60	.08	.04	.12	
Po-4	41°10′	81°06′	do	225	28.72	.11	.13	.24	
Ross, Ro-6	39°15′	83°09′	Gravel	78	2.62	.46	.44	.90	0.3 in. per day, 1:1.
Seneca, Se-2	41°08′	83°09′	Limestone	250	20.3(−.15)	.15	.15	.30	0.3 in. per day, 1:5.
Stark, St-5a	40°49′	81°20′	Gravel	132	29.25	.37	.30	.67	Do.
Trumbull, T-2	41°16′	80°51′	Sandstone	124	48.89(+.09)	.17	.13	.30	
Tuscarawas, Tu-1	40°36′	81°32′	Gravel	23	10.50(−.05)	.18	.26	.44	0.3 in. per day, 1:5.
Tu-2	40°36′	81°32′	do	200	48.89(+.09)	.10	.16	.26	
Tu-3	40°32′	81°29′	do	63	5.35	.30	.28	.58	0.3 in. per day, 1:10.
Tu-4	40°36′	81°32′	do	43	7.05	.30	.30	.60	0.3 in. per day, 1:5.
Van Wert, Vw-1	40°52′	84°33′	Limestone	340	27.10	3.10	2.70	5.80	No aftershocks recorded; 0.3 in. per day, 1:10.
Oklahoma									
Grady, 4N-8W-33	34°46′	98°03′	Rush Springs Sandstone	254	84.70			>1	No aftershocks recorded; 0.3 in. per day, 1:1.
Pontotoc, 1N-6E-4	34°34′	96°40′	Arbuckle Limestone	1,707	128.85			>1	Aftershocks recorded(?); 0.3 in. per day, 1:1.
1N-5E-27			do						Beaded cable slipped at time of quake.
Texas, 1N-12E-35	36°30′	101°44′	Ogallala Formation	386	192.37(−.13)			>1	No aftershocks recorded; 0.3 in. per day, 1:1.
Wagoner, 19N-16E-26	36°05′	95°34′	Alluvium	31	28.40	0.05	0.05	.10	0.3 in. per day, 1:1.
Washita, 10N-19W-10	35°21′	99°12′	Elk City Member of Quartermaster Formation.	55	37.17	.18	.18	.36	Do.
Oregon									
Yamhill, 4W-24J1	45°12′	123°07′	Alluvium	114/94	5.44(+.01)	0.045	0.01	0.055	Recorder tends to "hang up"; 2.4 in. per day, 1:6.
Pennsylvania									
Chester, Ch-152	40°08′	75°30′	Stockton Formation	750	LSD	Flow at LSD.	2.18	2.18	Flowing well; no aftershocks.
Cumberland, Cu-2	40°02′	77°18′	Ledger Dolomite	37	16.30(−.06)	.00	.08	.08	0.3 in. per day, 1:10.
Dauphin, 020-646-8	40°30′	76°46′	Martinsburg Shale	400	31.51(−.37)	.10	.71	.81	Do.[1]
020-646-9	40°20′	76°46′	do	185	23.96	.00	.20	.20	0.3 in. per day, 1:1.[1]
020-646-10	40°20′	76°46′	do	225	18.60	.00	.28	.28	Do.[1]
020-646-2	40°21′	76°46′	Limestone		6.29(−.17)			>1	Do.
Franklin, Fr-2	39°59′	77°39′	Stones River Limestone	441/60	28.0(?)	1.10	.65(+?)	1.75(+?)	Tape came off pulley; 0.3 in. per day, 1:10.
Fulton, Fu-1	40°03′	78°08′	Mauch Chunk Formation	108	3.45	.06	.09	.15	0.3 in. per day, 1:5.
Lackawanna, Dodge shaft	41°23′	75°41′	Coal mine		594.78	.61	.64	1.25	0.3 in. per day, 1:10.
Olyphant shaft.	41°27′	75°36′	do		716.61(+.03)	.32	.28	.60	Do.
Storrs 2 shaft	41°27′	75°38′	do		604.82	1.30	.88	2.18	0.3 in. per day, 1:5.
Lancaster, Ln-32(Ln-242)	40°09′	76°33′	New Oxford Formation	300	6.14(?)			>2	Beaded cable came off pulley; 0.3 in. per day, 1:2.
Luzerne, Lu-243	41°18′	76°15′	Catskill Formation	195	51.70			>1	No aftershocks recorded; 0.3 in. per day, 1:2.
Dennison St. Borehole.	41°19′	75°51′	Coal mine		512			>2	Aftershocks recorded (see table 6); 0.3 in. per day, 1:2.
Mercer, Mr-1364	41°22′	80°23′	Cussewago Formation	235	5.14	.13	.12	.25	Do.
Montgomery, Mg-225	40°08′	75°21′	Stockton Formation	300	38.20(+.30)	.30	.008	.308	Quake recorded at bottom of "low" in water level; 0.3 in. per day, 1:10.
York, Yo-180	40°03′	76°45′	New Oxford Formation	490	21.15(−.10)	.61	.97	1.48	Quake recorded at bottom of "low" in water level; 0.3 in. per day, 1:5.
007-637-7	40°07′	76°37′	do	148	6.33	.49	.96	1.45	Quake recorded at bottom of "low" in water level; 0.3 in. per day, 1:2.
005-639-7	40°05′	76°39′	do	222	19.30	.24	.53	.77	Quake recorded at bottom of "low" in water level; 0.3 in. per day, 1:1.

[1] Records atypical, but similar in all three wells.

TABLE 7.—*Hydroseisms in wells in the United States caused by the Alaska earthquake*—Continued

County, well	Latitude, N.	Longitude, W.	Water-bearing formation	First number, depth of well; second, depth of casing to screen, perforated casing, or open hole (feet)	Depth to water (feet)	Water-level fluctuation (feet): From preearthquake level: Upward	Water-level fluctuation (feet): From preearthquake level: Downward	Water-level fluctuation (feet): Double amplitude	Remarks
Puerto Rico									
Santa Isabel, Jauca 2	18°01′	66°22′	Tuffaceous clastics	300	82.50(?)	1.60	1.80	3.40	No aftershocks recorded; beaded cable slipped on pulley. Well is in a graben of a fault zone; 2.4 in. per day, 1:6.
Lajas, La Parguera	17°58′	67°02′	Limestone	92	38.30	.30	.29	.59	2.4 in. per day, 1:1.
Bayamón, Fort Buchanan	18°24′	66°08′	Sand, limestone, and clay.	242	37.52	.01	.01	.02	Quake recorded at bottom of water-level "low"; 0.3 in. per day, 1:1.
Vega Alta, Sabana Hoyos	18°26′	66°20′	Limestone	94	+29.22	.08	.06	.14	Another quake(?) recorded 60 hrs later; 0.3 in. per day, 1:1.
Rhode Island									
No wells recorded the earthquake.									
South Carolina									
Beaufort, BFT-101	32°10′	80°44′	Ocala(?) Limestone		15.14(−.36)			>2	
BFT-304	32°08′	80°50′	do	649	7.4(?)	4.49	4.49	8.98	Beaded cable thrown off pulley.
Florence, FLO-126			Upper Cretaceous sand	705				.22	
Jasper, J-46	32°18′	80°58′	Ocala(?) Limestone	334	22.83	1.97	2.75	4.72	Aftershocks recorded (see table 6).
Lexington, LEX-79			Upper Cretaceous sand	280				1.17	
Orangeburg, ORB-5	33°	81°	Chlorite-hornblende schist.	1,839				.90	
ORB-7	33°	81°	do	1,969				.30	
Richland, RIC-200	34°	81°	Crystalline rocks					.21	
South Dakota									
Beadle, Huron 2	44°	98°	Basal sand of glacial drift.	74	15.27	0.06	0.06	0.12	0.3 in. per day, 1:5.
113-63-2bbbb	44°37′	98°22′	Glacial outwash	155/71	28.52(−.05)	.05	.07	.12	0.3 in. per day, 1:2.
111-63-15bc2	44°25′	98°23′	do	52/2	16.65(+.03)	.053		.053	0.3 in. per day, 1:1.
Lawrence, A-7-2-10badc	44°	103°	Opeche and Minnelusa Formations.	1,306/1,266	+121	12	11	23	Pressure recorder; 51° per day, 1:558, no aftershocks recorded.
Tennessee									
Campbell, Cb: 0-6	36°34′	84°07′	Rockcastle(?) Sandstone	620	74.99	>1	>1	>2	0.3 in. per day, 1:1. Pen thrown off recorder by quake.
Crockett, Ck: B-5	35°42′	89°05′	Claiborne Group ("500"-foot sand).	537	40.16	.27	.34	.61	0.3 in. per day, 1:2.
Dickson, Di: F-19	36°04′	87°23′	Fort Payne Chert	387	23.00(−.07)	.35	.65	1.00	0.3 in. per day, 1:10.
Fayette, Fa: W-1	35°22′	89°33′	Wilcox Group ("1400"-foot sand).	1,025	73.98	.03	.15	.18	0.3 in. per day, 1:2.
Fa: W-2	35°22′	89°33′	Claiborne Group	365	41.36	.02	.04	.06	Do.
Franklin, Fr: F-1	35°03′	86°16′	Fort Payne Chert	100	30.60	.105	.105	.21	Do.
Humphreys, Hs: H-1	36°01′	87°57′	do	187	86.70	>1	>1	>2	0.3 in. per day, 1:1. Pen thrown off recorder by quake.
Madison, Md: N-1	35°42′	88°37′	Ripley Formation	659	128.6	.12	.14	.26	0.3 in. per day, 1:1.
Shelby, Sh: J-1	35°00′	90°05′	Claiborne Group	334	42.17	2.86	1.04	3.90	One aftershock recorded (see table 6); 0.3 in. per day, 1:2.
Sh: K-75	35°05′	89°55′	Terrace deposit	91	44.6	.12	.09	.21	0.3 in. per day, 1:2.
Sh: L-1	35°03′	89°51′	Claiborne Group	578	93.58	.005	.00	.005	0.3 in. per day, 1:1.
Sh: L-15	35°04′	89°45′	do	220	74.91(−.03)	.145	.04	.185	Do.
Sh: O-170	35°09′	90°01′	Wilcox Group	1,387	73.3	.05	.05	.10	0.3 in. per day, 1:10.
Sh: O-179	35°09′	90°02′	Claiborne Group	472	117.5	.42	.38	.80	Do.
Sh: P-1	35°13′	89°54′	do	344	101.62	.79	.42	1.21	0.3 in. per day, 1:2.
Sh: Q-1	35°09′	89°48′	do	384	90.44	.017	.13	.147	0.3 in. per day, 1:1. Water level declined 0.13 ft in 24 hrs after quake.
Sh: Q-24	35°13′	89°52′	do	336	69.36	.10	.04	.14	0.3 in. per day, 1:2.
Sh: U-1	35°21′	89°57′	Wilcox Group	1,558	53.8	.47	.49	.96	2.4 in. per day, 1:2.4.
Sh: U-2	35°21′	89°57′	Claiborne Group	440	51.1	.96		>1.00	Do.
Tipton, Tp: E-3	35°26′	89°47′	do	496/466	197.49	.24	.30	.54	1.2 in. per day, 1:2.
Williamson, Wm: M-1	35°55′	86°54′	Knox Dolomite	1,160	85.37	.00	.27	.27	0.3 in. per day, 1:1. Water level declined 0.27 ft in 16 hrs after quake.

TABLE 7.—*Hydroseisms in wells in the United States caused by the Alaska earthquake*—Continued

County, well	Latitude, N.	Longitude, W.	Water-bearing formation	First number, depth of well; second, depth of casing to screen, perforated casing, or open hole (feet)	Depth to water (feet)	Water-level fluctuation (feet): From preearthquake level: Upward	Water-level fluctuation (feet): From preearthquake level: Downward	Water-level fluctuation (feet): Double amplitude	Remarks
Texas									
Bexar, D-59	29°34′	98°41′	Edwards Limestone	400	279.26	1.31	1.75	3.06	Float hung after major wave.
F-172	29°32′	98°28′	do	500	124.10	>2.1	>2.9	>5	Aftershocks recorded (see table 6); 2.4 in. per day, 1:6.
F-214(169a)	29°35′	98°30′	do	547/100	278.45	.11	.18	.29	
J-17	28°29′	98°26′	do	874	76.90	>2.90	>2.10	>5	Do.
Comal, G-49	29°42′	98°08′	do	230/27		.08	.05	.13	
H-36	29°35′	98°19′	do	292/220		1.14	1.17	2.31	
H-39	29°37′	98°18′	do	250		.05	.06	.11	
Dallas, C-19	32°59′	97°00′	Woodbine Sand	268/100		.20	.19	.39	
El Paso, Q-86(CR-1)	31°56′	106°36½′	Alluvium	200/100	21.54(−.10)	.11	.21	.32	2.4 in. per day, 1:6.
Q-176(CR-2)	31°57′	106°37′	Bolson deposits	1,072/585	47.27	.76	.62	1.38	Do.
Q-181			do	1,013/528		.45	.71	1.16	
Q-182(CR-4)	31°58′	106°37′	Alluvium	202/102	13.39	.26	.29	.55	Do.
Q-203(CR-5)	31°56′	106°37′	Bolson deposits	700/355	31.76	.79	>.25	1.6E	
V-42	31°47′	106°22′	do	710/380		.06	.00	.06	
Galveston, E-93	29°23′	95°06′	Sand	870	131.37	.05	.05	.10	Do.
L-61	29°22′	95°04′	do	850	114.2	.82	.38	1.20	2.4 in. per day, 1:12.
Harris, W-109	29°54′	95°08′	Beaumont Clay	196	91.31(+.015)	.24	.30	.54	0.3 in. per day, 1:1.
895	29°42′	95°16′	Gulf Coast aquifer	1,651/1,027		.40	.65	1.05	
Jackson, PP-80-03-101	28°59′	96°42′	do	590/150	59.13(−.06)	2.9	2.9E	5.8E	Aftershocks recorded (see table 6); 2.4 in. per day, 1:6.
PP-66-60-605	29°03′	96°31′	do	140		.21	.17	.38	
Medina, C-9-53	29°29′	99°08′	Edwards Limestone	247		.52	.36	.88	
I-2-25a	29°27′	99°17′	do	538				>5	
J-1-82	29°21′	98°53′	do	712				>2	
Uvalde, H-2-23	29°27′	99°40′	Edwards Limestone	237		.24	.35	.59	
H-2-30	29°22′	99°42′	do	721		.25	.16	.41	
H-3-23	29°26′	99°30′	do	201				>5	
H-5-1	29°12′	99°46′	do	350		.55	.50	1.05	
Val Verde, XV-1a	29°22′	100°48′	do	750	80.2	.65	.65	1.30	2.4 in. per day, 1:6.
Utah									
Davis, (B-2-1) 24bad3	40°53′	111°54′	Alluvium	386	(+)29	1	1	2	Pressure recorder. 51° per day, 1:115.
Juab, (D-11-1) 8aad1	40°52′	111°59′	do	100	12.24(−.02)	.27	.21	.48	0.3 in. per day, 1:1.
Millard, (C-16-7) 12dcd	39°24′	112°35′	do	?	(+)21.2	1.0	.2	1.2	Pressure recorder. 51° per day, 1:129.
(C-16-8) 21bcb1	39°25′	112°45′	do	988/118	3.97	1.30	1.20	2.50	2.4 in. per day, 1:6.
(C-19-5) 4ddd1	39°11′	112°24′	do	521	32.74(−.06)	.04	.06	.10	Do.
Salt Lake, (C-3-1) 32cad2	40°30′	111°58′	do	218	27.06(−.06)	.04	.15	.19	1.2 in. per day, 1:1.
(C-4-1) 23dbd1	40°26′	111°54′	do	152	52.87(?)	.22	.23	.45	Float hung at time of quake; 0.3 in. per day, 1:1.
Tooele, (C-2-6) 36dcc1	40°35′	112°28′	do	176	92.36	.44	.58	1.02	0.3 in. per day, 1:2.
(C-3-2) 14bad1	40°33′	112°02′	do	1,000	324.42	>.58	>.42	>1	Aftershocks recorded (see table 6); 2.4 in. per day, 1:1.2.
(C-7-8)10cbd1	40°13′	112°44′	Alluvium	175	90.65	.16	.025	.185	Float may not have moved freely; 2.4 in. per day, 1:1.2.
(C-2-4)33aac1	40°36′	112°17′	do	182	18.50			>1	1.2 in. per day, 1:1.
Utah, (D-5-1)8dcc1	40°23′	111°51′	do	240	14.7(−.24)	1.48	1.66	3.14	1.2 in. per day, 1:6.
Weber, (A-6-1)11cab1	41°16′	111°48′	do	354	14.69(+.01)	.04	.024	.064	2.4 in. per day, 1:6.
(B-6-1)30cca1	41°13′	112°00′	do	756	35.17			>1	Aftershocks recorded (see table 6). Water level rose 0.08 ft in 8 hrs after quake; 1.2 in. per day, 1:1.
Vermont									
No wells recorded the earthquake.									
Virgin Islands									
St. Thomas	18°21′	65°00′	Andesite volcanic breccia and tuff.	220		0.02	0.03	0.05	
Virginia									
Page	38°	78°	Basalt of Catoctin Formation.	280	44.85(+0.50)	1.16	0.45	1.61	The aquifer of metamorphosed basalt is steeply dipping; 2.4 in. per day, 1:12.

TABLE 7.—*Hydroseisms in wells in the United States caused by the Alaska earthquake*—Continued

County, well	Latitude, N.	Longitude, W.	Water-bearing formation	First number, depth of well; second, depth of casing to screen, perforated casing, or open hole (feet)	Depth to water (feet)	Water-level fluctuation (feet): From preearthquake level, Upward	Water-level fluctuation (feet): From preearthquake level, Downward	Water-level fluctuation (feet): Double amplitude	Remarks
Washington									
Grant, 14/25-28E1	46°40′	119°42′	Ringold Formation	648/492	472.83(−.03)	0.05	0.07	0.12	
15/26-28Q1	46°45′	119°41′	Yakima Basalt	892	307.80(+.66)	.08	.08	.16	Water rose 1.20 ft within 4 hrs after first shock wave and stayed that way; 2.4 in. per day, 1:1.2.
Pierce, 20/3-18C1	47°10′	122°23′	Vashon outwash sand and gravel.	185/152	101.60	1.97	1.95	3.92	Aftershocks recorded (see table 6); 1.2 in. per day, 1:10.
Spokane, 25/43-13H1	47°40′	117°20′	Sand and gravel	71/65	66.53	.01	.01	.02	
26/45-32J2	47°44′	117°10′	do	155	130.42	.57	.65	1.22	2.4 in. per day, 1:6.
Thurston, 17/2-19M2	46°56′	122°36′	do	97	23.87	.03	.03	.06	
Yakima, 12/17-8N1	46°32′	120°43′	Basalt	212	10.79	.12	.22	.34	
West Virginia									
Berkeley, 20-5-7	39°27′	77°58′	Beekmantown Limestone	250	38.58	0.15	0.15	0.30	1.2 in. per day, 1:5.
Wisconsin									
Dane, Dn-9/11/34-4	43°12′	89°10′	St. Peter Sandstone	70	51.11(+.01)	0.09	0.00	.09	0.3 in. per day, 1:1.
Dn-8/6/26-11	43°08′	89°44′	Pleistocene sand and gravel.	59	13.29	.17	.00	.17	Do.
Dodge, Dg-11/16/5-4	43°27′	88°37′	Cambrian and Ordovician sandstone	475	119.04(+.81)	.81	.19	1.00	0.3 in. per day, 1:10.
Fond du Lac, Fl-15/17/11-12	43°47′	88°25′	do	817	67.97(−.42)	.50	.66	1.16	Do.
Kenosha, Ke-2/20/18-19B	42°37′	88°11′	Sand and gravel	74	1.46(+.02)	.02	.05	.07	
Ke-1/22/13-46	42°32′	87°50′	Dolomite	125	21.33	.13	.05	.18	
Marinette, Mt-30/23/19-5	45°03′	87°44′	Cambrian and Ordovician sandstone.	703	20.35(+3)	>3.35	>.17	>3.52	Pen caught at edge of chart; 1.2 in. per day, 1:10.
Milwaukee, Ml-7/22/29-45	43°02′	87°54′	Milwaukee Formation	1,015	47.70	.43	.34	.77	0.3 in. per day, 1:10.
Ml-7/22/17-120	43°04′	87°54′	do	400	(+7.8)			>12E.	Aftershocks recorded (see table 6).
Ml-6/21/32-148	42°56′	88°01′	do	179	35.57			>2	
Monroe, Mo-8/2W/29-17	44°00′	90°39′	Cambrian sandstone	192	5.26(+1.43)	1.43		1.43	Permanent rise of 1.43 ft; 1.2 in. per day, 1:6.
Portage, Pt-23/8/13-410	44°28′	89°30′	Sand and gravel	90	7.52(−.01)	.09	.09	.18	1.2 in. per day, 1:1.
Sauk, Sk-10/6/3-1	43°22′	89°46′	Cambrian sandstone	426	81.78	.10	.10	.20	1.2 in. per day, 1:6.
Sheboygan, Sb-15/21/28-19	43°44′	87°59′	Niagara Dolomite	450	3.18	1.21	1.29	2.50	1.2 in. per day, 1:10.
Waukesha, Wk-6/19/2-14	43°00′	88°13′	Cambrian and Ordovician sandstone.	1,300	351.45(+.45)	.45	.00	.45	0.3 in. per day, 1:10.
Waupaca, Wp-21/11/9-63	44°18′	89°10′	Pleistocene sand and gravel.	94	21.49(−.03)	.37	.35	.72	1.2 in. per day, 1:6.
Wp-22/14/12-13	44°23′	88°44′	do	203	11.25(−.01)	.08	.03	.11	Do.
Wyoming									
Laramie, 14-67-18ddc	41°11′	104°56′	Siltstone of Brule Formation.	311	20.26	0.03	0.03	0.06	
Platte, 29-69-24dbc2	42°28′	105°04′	Hartville Formation	840	15.18	1.00	1E.	2E.	No aftershocks recorded; 2.4 in. per day, 1:6.

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