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DEPARTMENT OF THE INTERIOR
Geological Survey

LAND SUBSIDENCE AND TECTONISM

RAFT RIVER VALLEY, IDAHO

By Ben E. lder Lofgren, 1918-

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CONVERSION FACTORS

Factors for converting English units to the International System of Units (SI) are given below to four significant figures. However, in the text the metric equivalents are shown only to the number of significant figures consistent with the values for the English units.

English	Multiply by	Metric (SI)
acres	4.047×10^{-1}	ha (hectares)
acre-ft (acre-feet)	1.233×10^{-3}	hm^3 (cubic hectometres)
ft (feet)	3.048×10^{-1}	m (metres)
ft (feet)	30.48	cm (centimetre)
mi (miles)	1.609	km (kilometres)
mi^2 (square miles)	2.590	km^2 (square kilometres)

LAND SUBSIDENCE AND TECTONISM, RAFT RIVER VALLEY, IDAHO

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ABSTRACT

A comparison of 1974 leveling data with elevations established 40 years earlier reveals two types of vertical ground movement which have occurred in Raft River Valley, Idaho: (1) regional differential movement of about 0.22 ft (6.4 cm), apparently due to tectonism, and (2) extensive land subsidence of as much as 2.61 ft (0.80 m) caused by withdrawal of ground water. Data are too sparse to calculate the magnitude or areal extent of subsidence; however, tentative lines of equal subsidence suggest that the area affected by subsidence probably exceeds 100 mi^2 (260 km^2).

In order to estimate historic subsidence or subsidence potential in Raft River Valley serious consideration should be given to a field program of basic-data collection. Leveling along a few carefully selected lines of existing control and the installation and operation of extensometer/water-level recorders in areas of continuing water-level decline would provide useful data for evaluating past and estimating future subsidence.

INTRODUCTION

As part of a continuing investigation of possible ground movement in areas of geothermal interest, bench marks in Raft River Valley, Idaho, were releveled in fall 1974. This resurvey brought to light significant elevation changes that have occurred in the valley since bench marks were first leveled 40 years earlier. Two different types of ground movement are suggested by these measured changes: (1) an unclear configuration of regional differential movements, probably due to tectonism, and (2) a poorly defined cone of subsidence in a broad area of water-level decline. This brief report presents the results of the 1974 releveling program in relation to the hydrogeologic conditions in Raft River Valley.

When initiated, the 1974 releveling was to include only the bench marks south of Malta (fig. 1) in the region of greatest geothermal interest. After inspecting an extensive earth fissure 10 mi (16 km) north of Malta, however, and recognizing this as a tension feature related to a large cone of pumping drawdown, the releveling program was expanded to include an area extending about 15 mi (24 km) north of Malta. Financial cooperation for the expanded program was provided by the Idaho Department of Water Resources.

All of the geologic and ground-water background data for this study are from two published U.S. Geological Survey reports (Nace and others, 1961; and Mundorff and Sisco, 1963). For additional information, the reader is referred to these earlier reports.

In conjunction with the 1974 releveling, additional bench marks were added to the existing network to monitor future changes at strategic locations around the valley margin. Also, several lines of horizontal control (not described in this report) were established for future surveillance of possible horizontal ground movement. In this study, we are attempting to measure whatever vertical or horizontal ground movement may be occurring in the region before geothermal developments begin, so that possible changes caused by geothermal production might be more adequately defined.

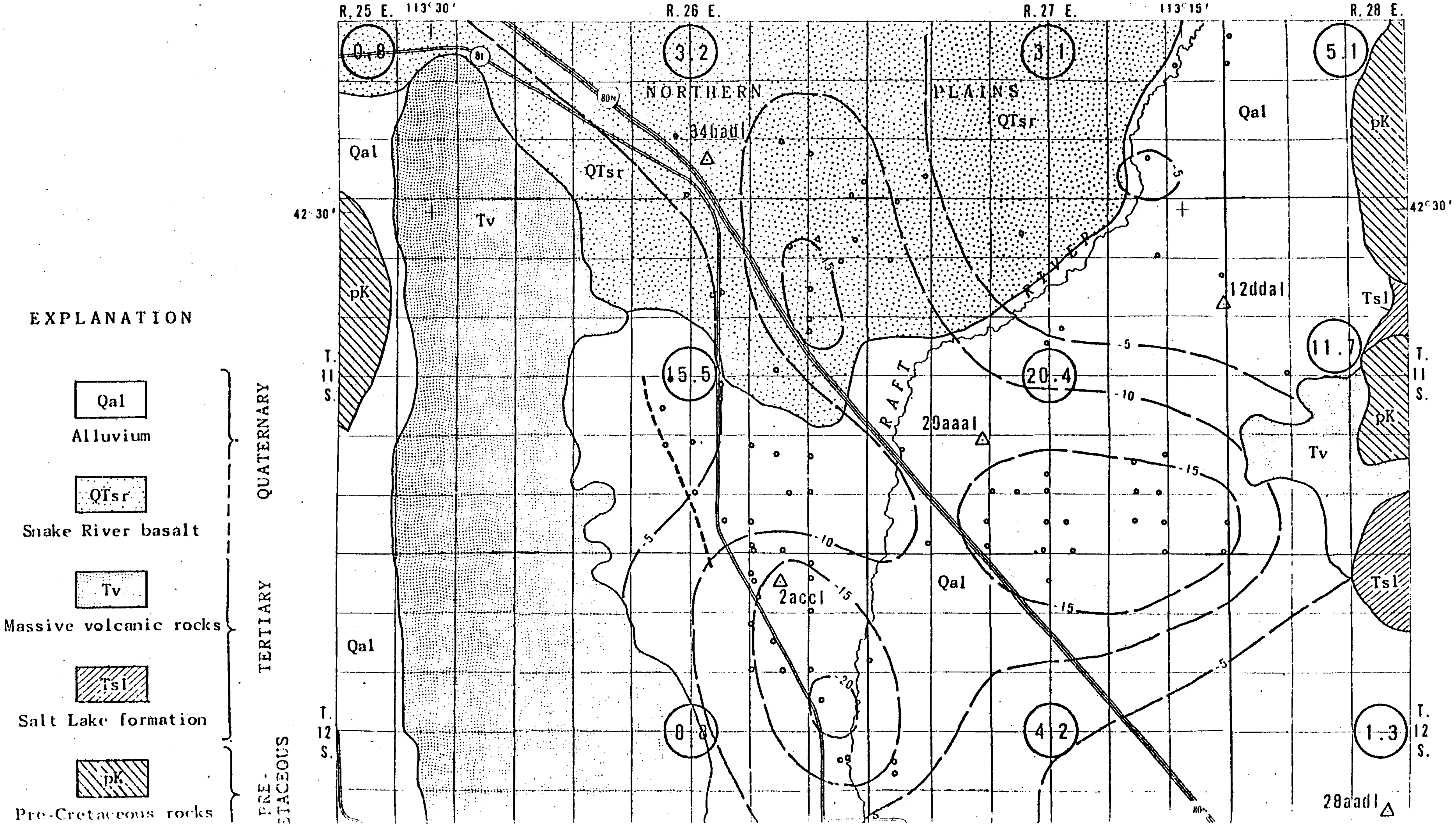
WELL-NUMBERING SYSTEM

Water wells are referred to in this report by numbers which indicate their locations within legal rectangular subdivisions of the public lands, with reference to the Boise base line and meridian. The first two segments of a number designate the township and range. The third segment gives the section number, followed by three letters and a numeral which indicate the quarter section, the 4-acre tract, and the serial number of the well within the tract. Quarter sections are lettered a, b, c, and d in counterclockwise order, from the northeast quarter of each section. Within the quarter sections, 40-acre tracts are lettered in the same manner. Thus, well 11S-27E-12dda1 is in the NE$\frac{1}{4}$ SE$\frac{1}{4}$ SE$\frac{1}{4}$, sec. 12, T. 11 S., R. 27 E, and is the well first visited in that tract.

HYDROGEOLOGIC SETTING

The accelerated use of ground water for irrigation in Raft River Valley has resulted in rapid water-level declines in areas of heaviest pumping. Pumpage in the Raft River Basin, which includes somewhat more irrigated acreage than considered in this report, increased from about 8,600 ac ft (11 hm^3) in 1948 to 235,000 ac ft (290 hm^3) in 1966 (Walker and others, 1970, p. 3). Hydrographs suggest a cessation of water-level declines in many parts of the valley beginning about 1970. Figure 1 shows the location of irrigation wells in 1960, and also, generalized 9-year change in water level in Raft River Valley from 1952 to 1961. As shown, water levels declined roughly 1 ft (0.3 m) per year in areas of heaviest pumping from 1952 to 1961. Water-level declines of as much as 50 ft (15 m) between spring 1952 and spring 1966 were reported in several areas of heavy pumping north of Malta by Walker and others (1970, fig. 20). Locally, however, long-term declines (fig. 3) exceed 100 ft (33 m), and rates of decline during the sixties were greater than 15 ft (5 m) per year.

Figure 1 near here.


EXPLANATION
Qal
Alluvium
QTsr
Snake River basalt
Tv
Massive volcanic rocks
Tsl
Salt Lake formation
pK
Pre-Cretaceous rocks
QUATERNARY
TERTIARY
PRE-CRETACEOUS
R. 25 E.
113°30'
R. 26 E.
R. 27 E.
113°15'
R. 28 E.
42°30'
T. 11 S.
T. 12 S.
NORTHERN PLAINS
RAFT RIVER
81
80N
0.8
3.2
3.1
5.1
15.5
20.4
11.7
4.2
1.3
34bad1
12dda1
29aaa1
2acc1
28aad1
-5
-10
-15
-20

▨ pK

Pre-Cretaceous rocks } PRE-CRETACEO

△ 33cddl

Observation well and number with hydrographs in this report

●

Irrigation well (From pl. 1, Mundorff and Sisco, 1963)

——— ——— -15 ——— ———

Line of equal change in water level from about 1952 to 1961, in feet (From pl. 1, Mundorff and Sisco, 1963)

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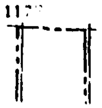
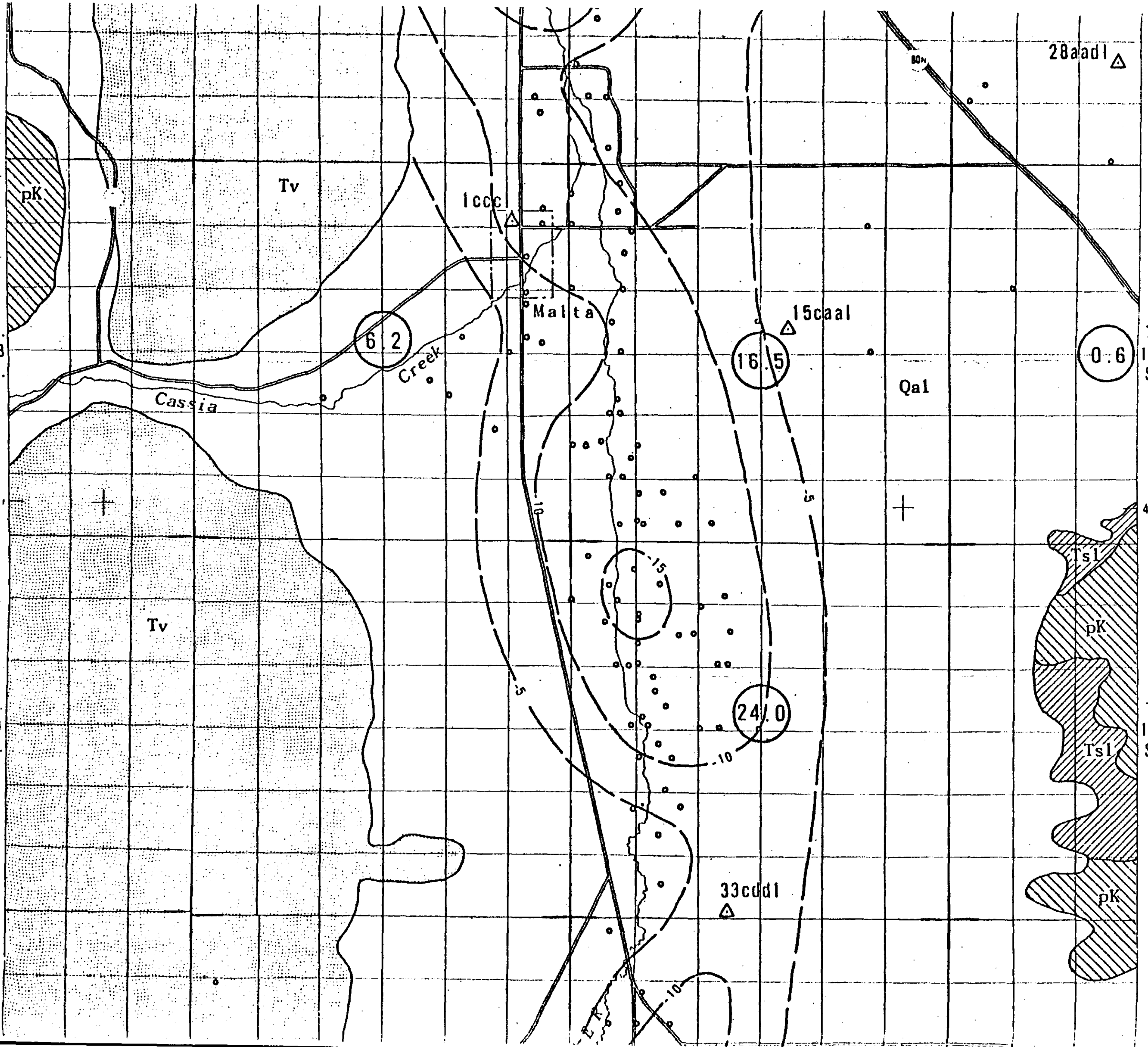
Earth fissure

(20.4)

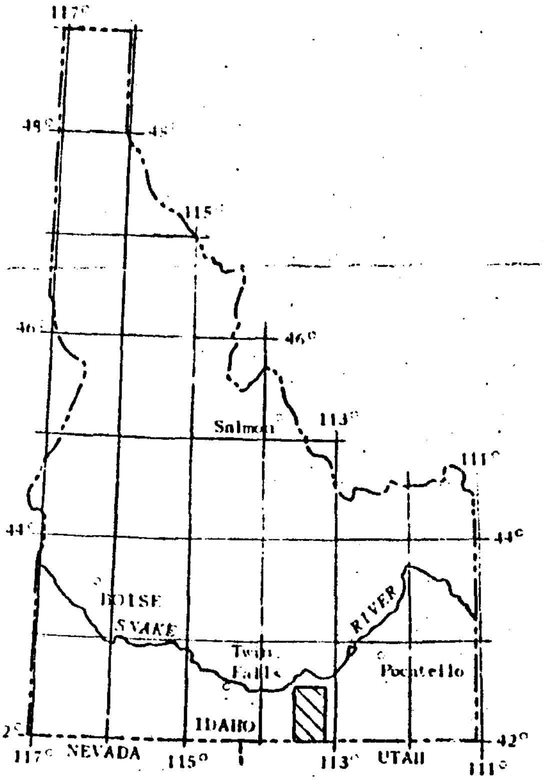
Estimated ground-water pumpage per township in 1960, in thousand acre-feet. (From table 1, Mundorff and Sisco, 1963)

NOTE:
To convert feet to metres, multiply by 0.3048

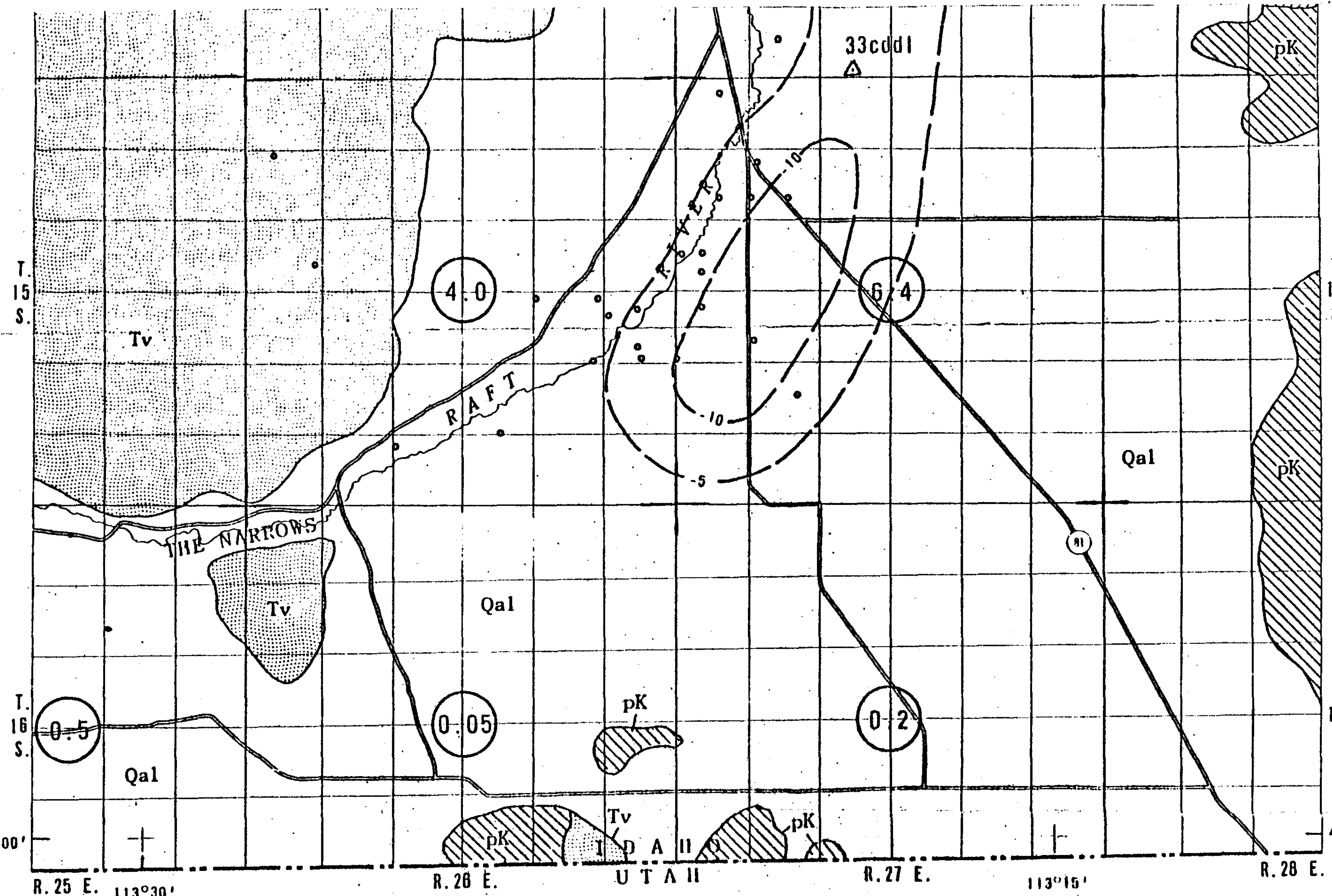




To convert feet to metres,
multiply by 0.3048



Index map of Idaho showing location of study area



Base from State of Idaho Department of Highways, 1973; scale 1:126,720

FIGURE 1.—Location of irrigation wells, selected observation wells, 1952-61 change in water level, and generalized geology, Raft River Valley, Idaho.

(Geology modified from Nace and others, 1961)

In general, the ground water pumped in Raft River Valley is derived from the chiefly unconsolidated alluvial gravel, sand, and silt of the valley trough. However, basalt flows form part of the aquifer system at the north end of the valley. These deposits generally are very permeable; however, fine-grained beds locally confine ground water in the deeper aquifers. Small amounts of ground water are obtained from the consolidated rocks in the mountains surrounding the valley trough.

The configuration of water-level contours (Walker and others, 1970, fig. 14) and also lines of equal water-level change (fig. 1; Walker and others, 1970, fig. 20) in the northern part of the study area indicate a general northward gradient of water levels in the valley, with large cones of pumping drawdown where irrigation wells are clustered. The water contours cross smoothly from the alluviated part of the valley to the basalt-covered Northern Plains, suggesting a hydrologic continuity across these dissimilar areas. This continuity is readily apparent, however, when logs of wells penetrating the basalts are studied. As shown by the two selected well logs of table 1, the water-bearing unconsolidated sands and gravels of the valley underlie the basalt. Thus, continuity of the ground-water reservoir is little affected by the overlying Snake River basalt. As indicated later, the cone of subsidence caused by excessive pumping probably affects at least the southern margin of the Northern Plains.

Table 1.--Log of well 11S-26E-10db1

Material	Thickness (feet) 1/	Depth (feet) 1/
Soil and basaltic ash [?]	15	15
Basalt, hard	45	60
Cinders	5	55
Basalt	42	107
Clay	29	136
Cinders	6	142
Basalt, hard	79	221
Cinders	5	226
Basalt	8	234
Basalt, gravel, and clay	14	248
Gravel	10	258
Gravel and sand	7	265
Sand, clay, and gravel; small amount of water	5	270
Clay and gravel	3	273
Sand and gravel	5	278
Clay and gravel	40	318

Table 1.--Log of well 11S-26E-10 dbl--Continued

Material	Thickness (feet)[1]	Depth (feet)[1]
Crevice; drill cuttings not recovered	3	321
Gravel	27	348
Sand	3	351

[1] To convert feet to metres, multiply by 0.3048.

Table 2.—Log of well 11S-26E-12ab1

Material	Thickness (feet) [1]	Depth (feet) [1]
Soil	29	29
Basalt, brown	36	65
Basalt, black	10	75
Basalt, brown	23	98
Basalt, black, hard	4	102
Basalt, boulders	8	110
Basalt, loose, and gravel	13	123
Gravel and sand	1	124
Gravel, sand, and mud	9	133
Gravel, water-bearing	8	141
Clay, light gray	7	148
Clay, blue, sticky	7	155
Basalt, solid	26	181
Basalt, broken, and cinders. Water at 203 ft	22	203
Not recorded	47	250

1/ To convert feet to metres, multiply by 0.3048.

INTERPRETATION OF DATA

Figure 2 shows the network of bench marks in Raft River Valley

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Figure 2 near here.

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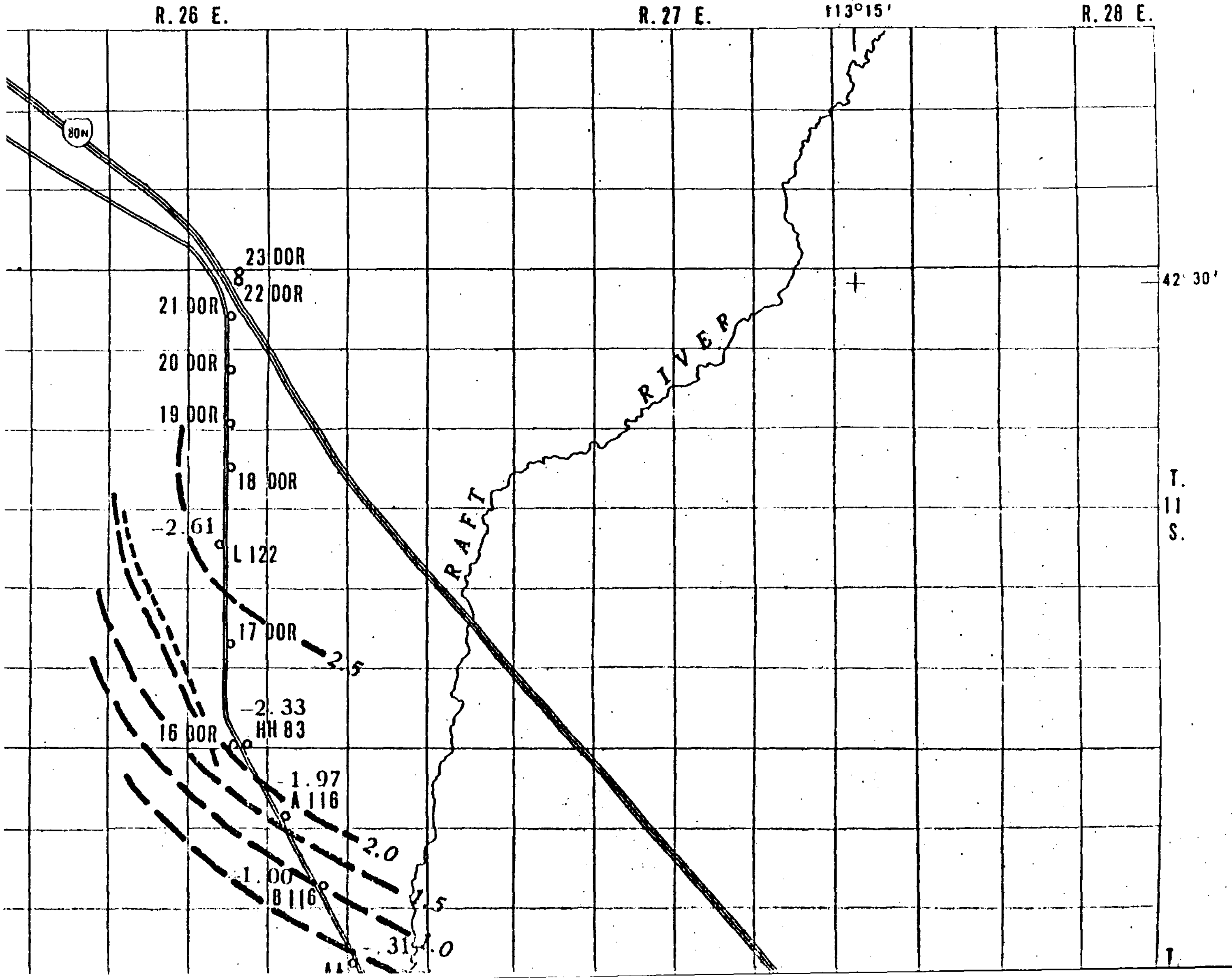
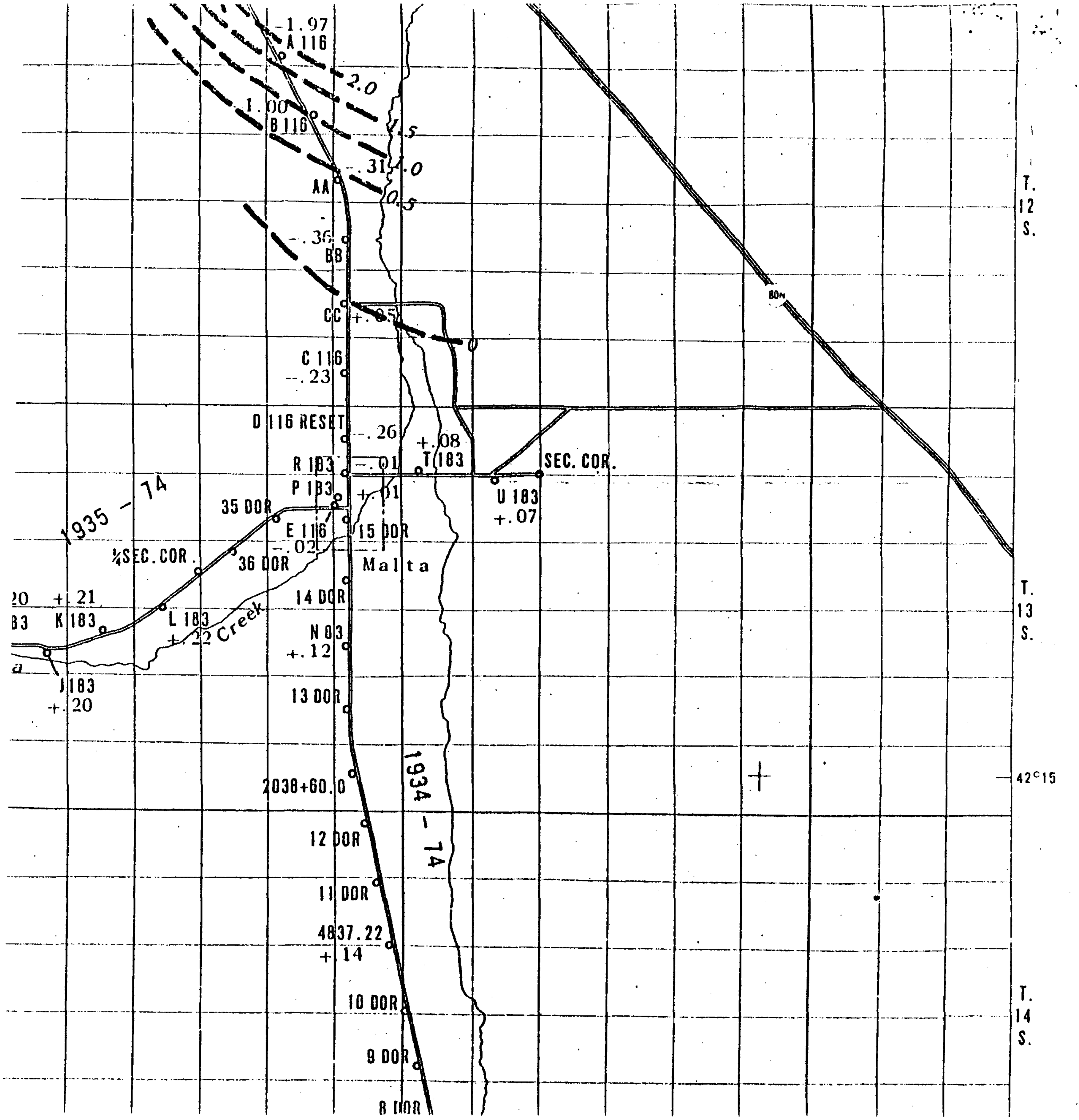
surveyed in fall 1974, and also the measured change in elevation for the 39 bench marks for which earlier elevations were available. Bench marks designated DOR were first surveyed in 1974. Bench marks with an HLS designation, on the line running southwest through The Narrows, were first surveyed in 1967 and changes shown are for the period 1967-74. All other bench marks were first surveyed in 1934-5, and elevation changes shown are for the 1935-74 period on the line west from Malta and 1934-74 on the north-south line along State Highway 81 through Malta. For the 1974 survey, two bench marks on State Highway 81 near the Utah state line (not shown in fig. 2) were held stable--that is, assigned the same elevation as in 1934—and new elevations were calculated for all other bench marks in the network. Elevation changes reported in this report, therefore, are relative to other bench marks in the net, and not absolute changes with respect to sea level. For future reference, bed rock ties were established in 1974 on the north and south sides of The Narrows of Raft River, the north and south sides of the narrows of Cassia Creek, and on the Snake River Basalts east of Interstate 80N about 14 mi (23 km) north of Malta. Also, a new line of leveling control was run eastward in Township 15 from Highway 81 to the eastern margin of the valley.


R. 26 E.
R. 27 E.
113°15′
R. 28 E.
42° 30′
T. 11 S.
T.
80N
RAFT RIVER
23 DOR
22 DOR
21 DOR
20 DOR
19 DOR
18 DOR
-2.61
L 122
17 DOR
2.5
-2.33
HH 83
16 DOR
-1.97
A 116
2.0
-1.00
B 116
1.5
-.31
1.0


-1.97
A 116
2.0
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B 116
-.31
AA
-.36
BB
CC
+.05
C 116
-.23
D 116 RESET
-.26
+.08
T 183
R 183
-.01
SEC. COR.
U 183
+.07
P 183
+.01
35 DOR
E 116
-.02
15 DOR
1935 - 74
¼SEC. COR.
36 DOR
Malta
14 DOR
20
+.21
83
K 183
L 183
+.22
Creek
N 83
+.12
a
J 183
+.20
13 DOR
2038+60.0
1934 - 74
12 DOR
11 DOR
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T. 12 S.
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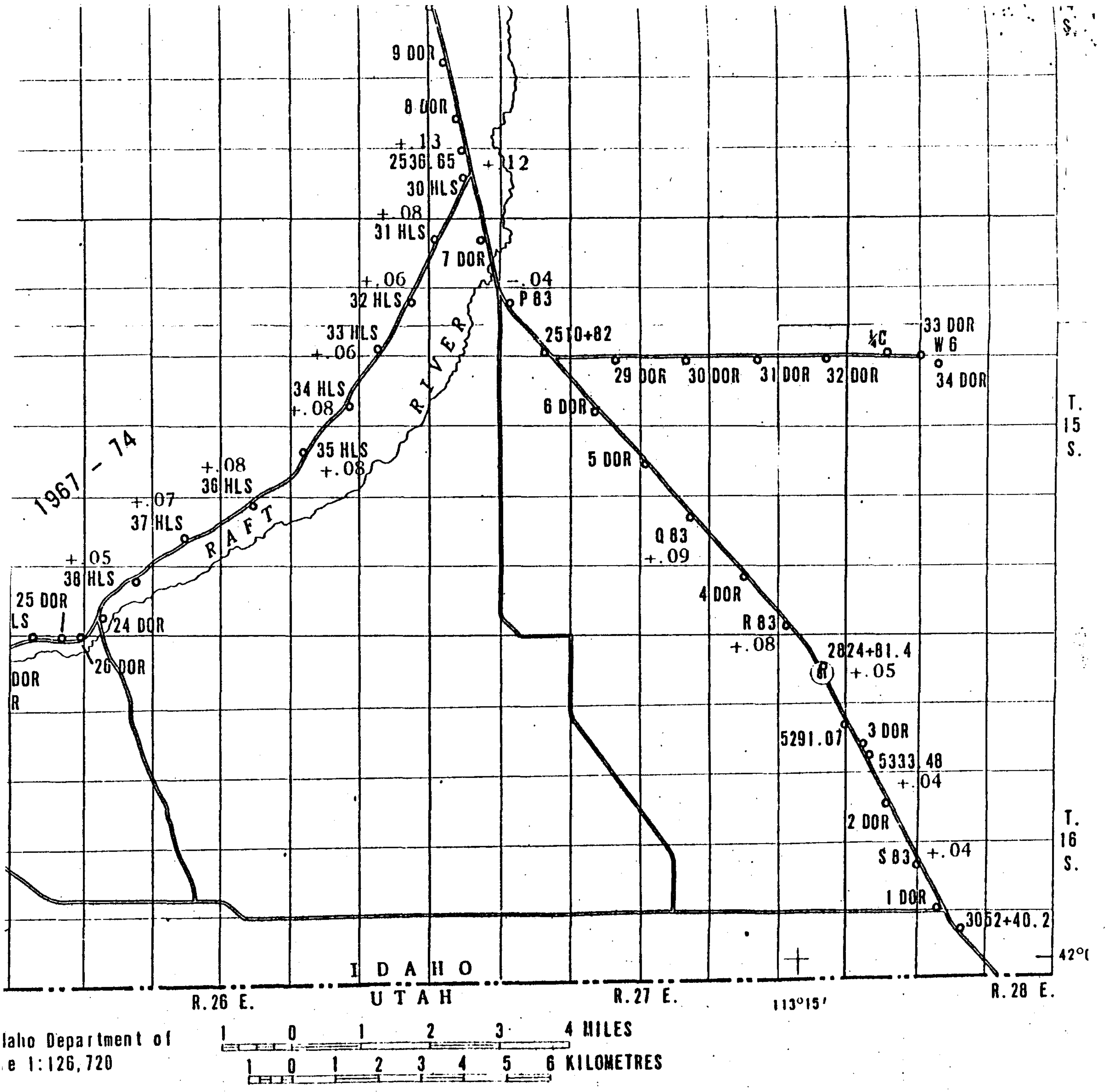
42°15



laho Department of
e 1:126,720

URE 2.—Measured change in elevation of bench marks, Raft River Valley, Idaho

Two significant types of vertical ground movement are indicated by the measured elevation changes of figure 2. These are (1) an apparent tectonic deformation in Cassia narrows of as much as 0.22 ft (6.4 cm) in 40 years, the pattern of which is not clearly understood; and (2) a cone of subsidence of probably more than 2.61 ft (0.80 m) that developed since 1934 north of Malta caused by ground-water declines. Because the 1934-5 and the 1974 leveling were of first-order accuracy, the error of closure should be less than 0.0166 ft times the square root of the distance in mi (4 mm times the square root of distance in km) of the traverse. Thus, in the 30 mi (48 km) from the point of beginning at the Utah line to the Cassia narrows west of Malta, the leveling error should be less than 0.091 (0.028 m). The calculated elevation changes along Cassia Creek (fig. 2), however, are more than twice these amounts, and increase systematically from the southeast corner of the area to Cassia narrows. During future surveys, changes across the Cassia Creek and Raft River narrows will be monitored closely where active faulting is suspected.

Tentative lines of equal subsidence (fig. 2) sketched through the subsidence area north of Malta are based on only seven points of measured change. The configuration of these lines has been influenced by: (1) the pattern of the lines of equal water-level change, (2) the configuration of the massive volcanic rocks (Tv), and (3) the trend of the earth fissure--features all shown in figure 1. Many more points of known subsidence would be necessary to adequately contour this subsidence depression. These tentative lines seem to fit most adequately the data available, and are the basis for several of the conclusions of this report. Interestingly, the location of the earth fissure marks the western limit of heaviest pumping in the area. Also, both the trend of the earth fissure (fig. 1) and the lines of equal subsidence (fig. 2) cut obliquely across the lines of 1952-61 water-level change, rather than being parallel as in most other areas that have been studied. This suggests that in the southern half of T. 11 S., R. 26 E., the lines of 1952-61 water-level change (fig. 1) are not a good representation of either the horizontal or vertical stresses that produced the tension fissure and the subsidence.

The trends of water levels in eight observation wells in Raft River Valley (fig. 3) show the long-term decline in the principal

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Figure 3 near here.

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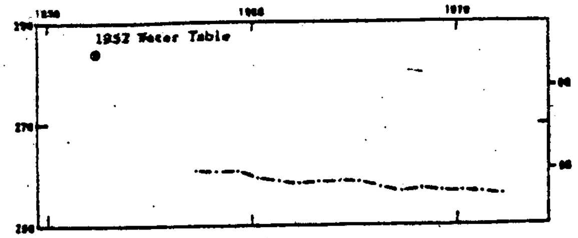
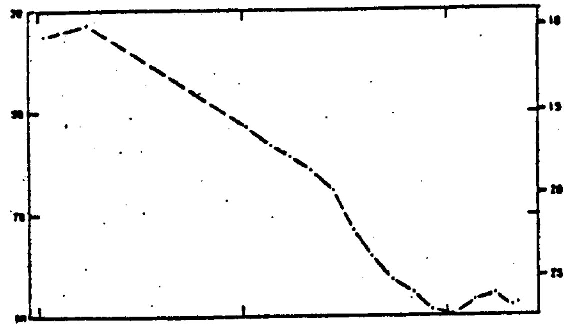
areas of ground-water pumping. These hydrographs show for each well the trend of the deepest measured water level each year. Inasmuch as stresses are a maximum when drawdowns are greatest, these modified hydrographs show the trend of maximum seepage stresses in the aquifer system that cause the horizontal and vertical compaction of the deposits (Lofgren, 1968). As shown, summer pumping levels declined 140 ft (43 m) at well 11S-27E-12dda1 from 1952 to 1971, and more than 90 ft (27 m) at well 12S-26E-2acc1 from 1950 to 1969. Probably, declines at other unmonitored locations exceeded these amounts. Most of the hydrographs show a rising trend of water levels since 1970.

Based on the sparse data presented above, the following tentative conclusions seem reasonable:

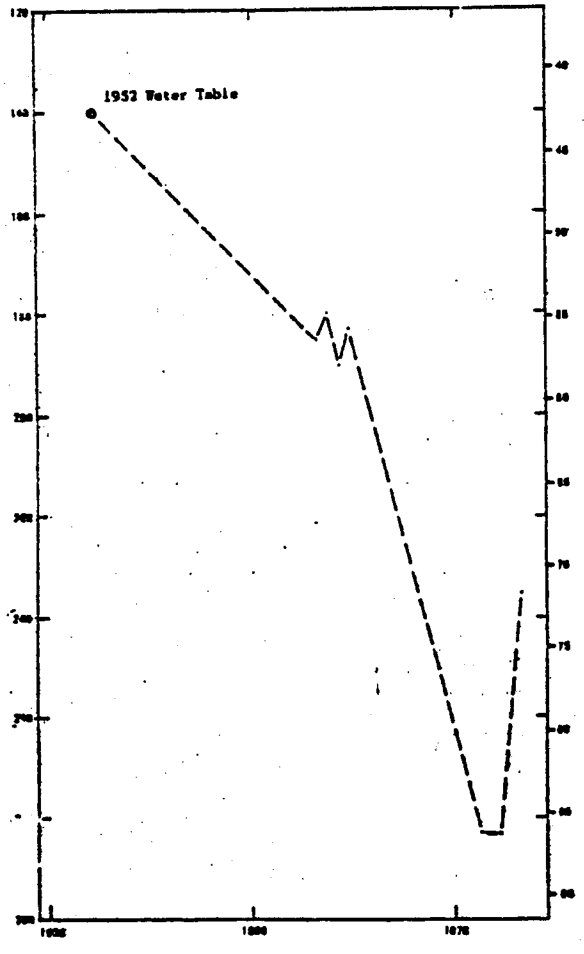
(1) Subsidence north of Malta is likely caused by the decline of water levels due to pumping of ground water. As in other subsidence areas studied, the subsidence here very likely results from the compaction of fine-grained water-bearing deposits due to increased effective stresses (Lofgren, 1968).



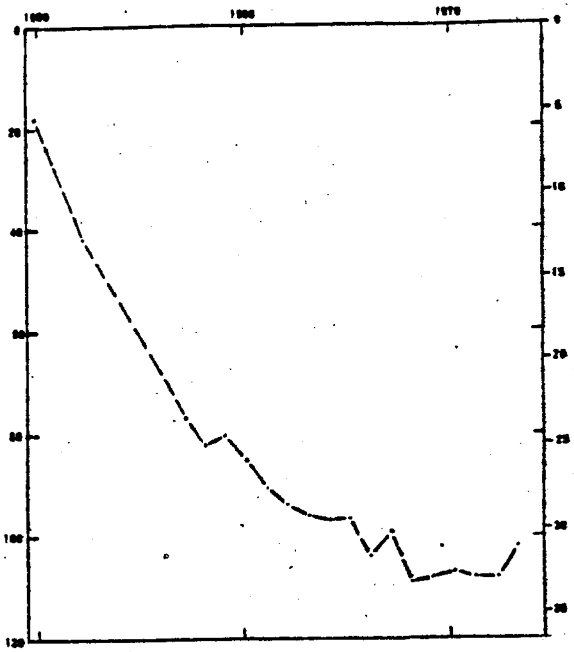
1. Well 10S-26E-34 bad2, 342 feet deep.



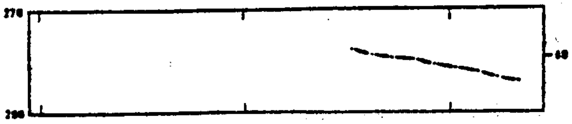
2. Well 11S-27E-29 aaa1, 247 feet deep.



3. Well 11S-27E-12 dda1, 376 feet deep.

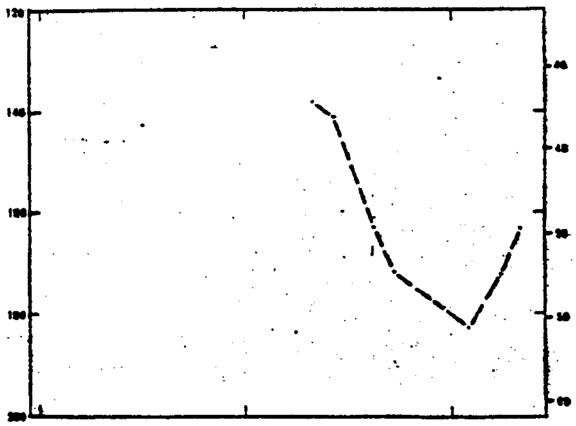


4. Well 12S-26E-2accl, 197 feet deep

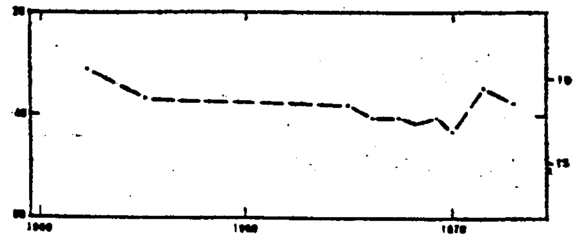


5. Well 12S-28E-28aad1, 285 feet deep

6. Well 13S-26E-1ccc1, deepened from 69 to 250 feet in 1961



7. Well 13S-27E-15caa1, 947 feet deep



8. Well 14S-27E-33 cdd1, 200 feet deep.

FIGURE 3.—Hydrographs of selected wells.

(2) The area of maximum subsidence is probably east of State Highway 81 and possibly east of Interstate Highway 80N. If so, then maximum subsidence is greater than the 2.61 ft (0.80 m) measured at bench mark L122.

(3) Part of the Northern Plains basalt terrain affected by significant water-level decline may have also subsided; however, the magnitude or extent of the subsidence is unknown. Bench marks 22DOR and 23DOR, which were set in 1974 in what appeared to be stable basalt, probably are not stable, although the hydrograph of nearby well 10S-26E-34bad2 since 1957 indicates little water-level decline at this location.

(4) The area affected by subsidence may exceed 100 mi^2 (260 km^2), and possibly half that area has subsided more than 1 ft (0.3 m) during the 40 years from 1934 to 1974.

(5) The conspicuous earth fissure, first observed during the early 1960's 10 mi (16 km) north and west of Malta (fig. 2), is similar to numerous tension fissures studied in other states. It appears to be a tension feature on the west margin of a cone of pumping drawdown, caused by horizontal compression of the water-bearing deposits induced by horizontal seepage stresses. The fissure apparently formed when drawdowns and thereby horizontal pumping stresses were sufficiently great to cause a slight shift of the ground toward the center of subsidence. There is no evidence that the fissuring has been active during the past few years of rising water levels.

(6) Both subsidence and fissuring are caused by stresses induced by the long-term decline of water levels in the ground-water reservoir. Although the rising trend shown by hydrographs suggests that these processes probably have slowed significantly since 1970, they may be reactivated at any time by further water-level declines.

NEED FOR ADDITIONAL DATA

Periodic resurveys of horizontal and vertical control networks south of Malta will be continued by the Geological Survey, as part of its geothermal research activities. As presently scheduled, however, these surveys will not include the area north of Malta. The following types of basic-data collection would be beneficial in analyzing future subsidence:

(1) Periodic water-level measurements in selected observation wells, located in areas of heaviest pumping.

(2) Periodic releveling of an additional line of bench marks through centers of maximum pumping drawdown, with surveys tied to stable bench marks outside the subsidence area.

(3) The installation of a wire-line or pipe extensometer (Lofgren, 1961), at a location near the center of maximum subsidence and extending to a depth greater than that reached by most of the pumping wells, to measure possible compaction of the water-bearing deposits.

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