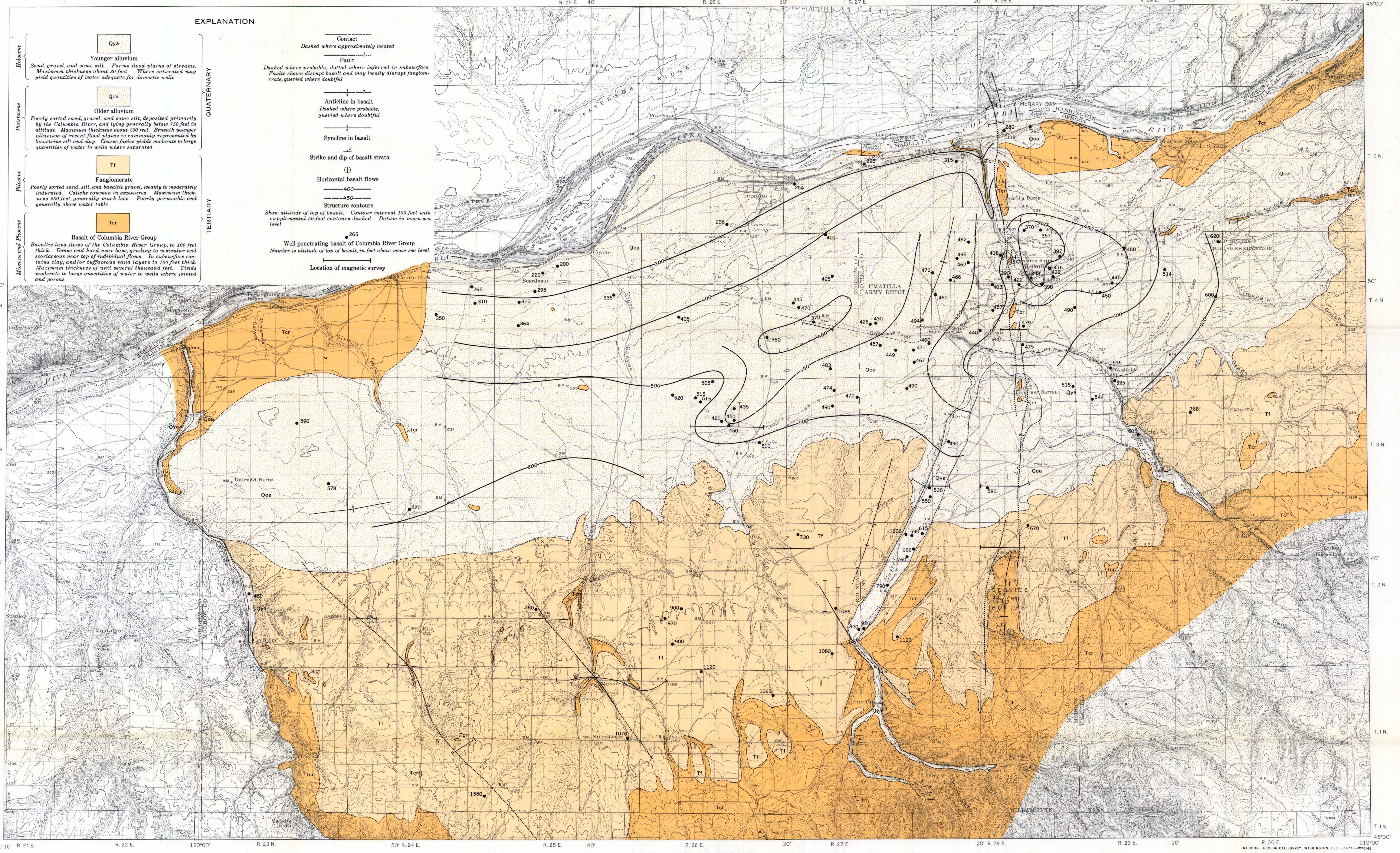
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH THE
OREGON STATE ENGINEER

HYDROLOGIC INVESTIGATIONS
ATLAS HA-387 (SHEET 1 OF 2)



EXPLANATION

Qya

Younger alluvium

Sand, gravel, and some silt. Forms flood plains of streams. Maximum thickness about 30 feet. Where saturated may yield quantities of water adequate for domestic wells

Holocene

Qoa

Older alluvium

Poorly sorted sand, gravel, and some silt, deposited primarily by the Columbia River, and lying generally below 750 feet in altitude. Maximum thickness about 200 feet. Beneath younger alluvium of recent flood plains is commonly represented by lacustrine silt and clay. Coarse facies yields moderate to large quantities of water to wells where saturated

Pleistocene

QUATERNARY

Tf

Fanglomerate

Poorly sorted sand, silt, and basaltic gravel, weakly to moderately indurated. Caliche common in exposures. Maximum thickness 250 feet, generally much less. Poorly permeable and generally above water table

Pliocene

Tcr

Basalt of Columbia River Group

Basaltic lava flows of the Columbia River Group, to 100 feet thick. Dense and hard near base, grading to vesicular and scoriaceous near top of individual flows. In subsurface contains clay, and/or tuffaceous sand layers to 100 feet thick. Maximum thickness of unit several thousand feet. Yields moderate to large quantities of water to wells where jointed and porous

Miocene and Pliocene

TERTIARY

Contact
Dashed where approximately located

Fault
Dashed where probable; dotted where inferred in subsurface. Faults shown disrupt basalt and may locally disrupt fanglomerate, queried where doubtful

Anticline in basalt
Dashed where probable, queried where doubtful

Syncline in basalt

Strike and dip of basalt strata

Horizontal basalt flows

400
450
Structure contours
Show altitude of top of basalt. Contour interval 100 feet with supplemental 50-foot contours dashed. Datum is mean sea level

● 265
Well penetrating basalt of Columbia River Group
Number is altitude of top of basalt, in feet above mean sea level

Location of magnetic survey

Base from U.S. Geological Survey 30'
topographic quadrangles, 1906–16

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D.C.—1971—W70146

Geology from G. M. Hogenson, 1953 and 1964,
revised and extended by J. H. Robison, 1967

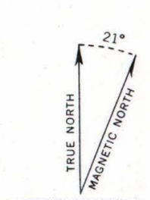
GEOLOGIC MAP

SCALE 1:125 000

2 0 2 4 6 8 10 MILES

2 0 2 4 6 8 10 KILOMETERS

CONTOUR INTERVAL 50 FEET
DATUM IS MEAN SEA LEVEL
ELEVATIONS SHOWN ON THIS SHEET ARE ONE FOOT TOO LOW



APPROXIMATE MEAN DECLINATION, 1971

SELECTED WELL DATA

Well number	Depth of well (feet)	[2]Use of water	[3]Driller's log	[4]Source of water	[5]Depth to top of basalt (feet)	Water level: Feet below land surface	Water level: Date measured or reported	Water level: Estimated current (1967) rate of change (feet per year)	Altitude of land surface (feet)
1N/24E-36aca	647	I	A	Basalt of Columbia River Group	59	500	1954	—	1610
1N/25E-10cdc	108	I	A	do.	12	68	1963	—	1000
13cdd	237	D	A	do.	34	160	1962	—	1130
1N/26E-10aac	376	I	A	do.	18	65	1964	—	1200
12baa	143	D	P	do.	100	24	1950	—	1165
24bbb	351	D	P	do.	1	135	1952	—	1410
25acd	492	D	—	do.	—	336	1952	—	1610
26cbd	230	I	A	do.	24	112	1963	−2	1420
1N/27E-3ddc	120	I	P	do.	29	5	1952	−2	1040
10adb	110	D	—	do.	90	25	1962	−4½	1050
24ddd	777	U	A	do.	31	F	1958	+2	1350
1N/28E-21dcc	270	U	P	do.	24	30	1953	—	1440
28bbd	365	I	P	do.	10	1	1967	0	1390
2N/23E-17ddd	425	I	A	do.	72	25	1964	−4	550
2N/25E-28bbb	30	U	—	do.	—	F	1953	—	850
2N/26E-19ddd	343	D	A	do.	294	168	1948	—	1010
35baa	114	D	—	—	—	32	1953	—	1045
[1]2N/27E-1bda	554	I	P	Basalt of Columbia River Group	170	334	1954	—	785
	840	I	—	do.	170	22	1961	—	785
	886	I	A	do.	170	F	1962	−9	785
6bdd	447	D	P	do.	284	280	1938	—	1010
11add	525	I	P	do.	63	F	1953	−10	825
12bba	959	I	A	do.	159	63	1959	−10	815
14cb	280	I	P	do.	88	45	1953	—	880
20daa	370	U	P	do.	35	250	1948	−3	1120
26cad	932	I	—	do.	52	88	1963	−5	1170
27bc	598	I	P	do.	30	50	1957	−13	950
32ad	445	D	A	do.	119	133	1962	—	1200
3N/23E-25bc	790	D	A	do.	34	143	1964	—	612
3N/24E-33ac	564	D	A	do.	30	198	1961	—	600
3N/26E-4aad	680	I	A	Basalt of Columbia River Group Older alluvium	127	156	1960	−5½	627
4ccc	358	I	P	Basalt of Columbia River Group	120	166	1955	—	635
5cbd	950	I	A	do.	120	174	1962	−6	641
10aba	544	I	A	Basalt of Columbia River Group Older alluvium	212	181	1956	−5	650
10cca	666	I	P	Basalt of Columbia River Group	172	155	1958	—	630
10dcc	168	D	A	Older alluvium	164	122	1962	−½	615
14da	197	I	P	Basalt of Columbia River Group	130	84	1954	—	640
3N/27E-2add	190	D	A	do.	101	30	1962	—	590
4dda	185	U	P	do.	89	34	1958	—	582
8aac	740	I	A	do.	100	62	1953	—	588
25ddd	591	U	A	do.	173	184	1963	−1½	720
36aaa	24	S	—	Older alluvium	—	14	1953	—	740
3N/28E-18db	875	I	A	Basalt of Columbia River Group	163	60	1956	—	650
28cbb	636	I	A	do.	130	280	1967	—	710
3N/29E-6dc	86	D	A	do.	52	7	1963	—	596
[1]16bdd	490	P	P	do.	25	95	1951	—	630
	820	P	A	do.	25	315	1964	—	630
4N/22E-35ba	305	D	A	do.	248	90	1965	—	306
4N/24E-13bc	115	D	A	do.	16	10	1960	—	280
17bd	216	D	A	do.	0	93	1965	—	300
22acc	100	D	A	do.	14	40	1954	—	365
4N/25E-8bd	178	P	A	do.	40	F	1946	—	260
8dad	585	P	A	do.	73	62	1965	—	295
4N/26E-25bcb	170	U	—	Older alluvium	—	46	1962	−1	550
4N/27E-5aba	710	P	P	Basalt of Columbia River Group	141	54	1957	−6	542
8dda	453	P	P	do.	190	138	1941	−3	615
18cdb	618	P	P	do.	140	110	1950	−11	585
19baa	600	P	P	do.	115	110	1950	−8	585
22cda	327	P	P	Basalt of Columbia River Group Older alluvium	157	90	1941	−1	585
22dbd	360	P	P	Basalt of Columbia River Group	155	80	1960	−2½	585
24db	125	I	A	do.	88	68	1957	—	582
26bcb	108	I	A	Older alluvium	—	73	1961	—	586
26cdd	496	U	A	do.	156	93	1957	—	605
27dad	543	D	P	Basalt of Columbia River Group	146	121	1943	—	603
28bca	102	I	P	Older alluvium	—	64	1953	—	567
32aba	104	I	A	do.	—	58	1961	—	566
32dab	310	I	P	Basalt of Columbia River Group	110	76	1961	−½	593
33dab	96	I	P	Older alluvium	—	69	1954	—	576
34bbc	102	I	A	do.	—	55	1958	—	565
36bba	812	I	A	Basalt of Columbia River Group	135	65	1958	−5½	582
4N/28E-1cdc	50	D	A	do.	48	18	1962	—	445
3bcd	56	D	A	do.	38	30	1963	—	470
5acb	85	D	A	do.	60	37	1964	—	522
7ddc	72	D	A	do.	64	20	1964	—	530
10bbc	105	D	A	do.	75	40	1964	—	465
10cca	207	D	A	do.	62	12	1965	—	452
10cda	500	P	A	do.	120	13	1963	—	450
11cac	918	P	A	do.	44	11	1954	—	446
11cca	962	P	A	do.	55	12	1954	—	453
12cc	65	D	A	do.	55	15	1965	—	495
14abb	510	D	A	Basalt of Columbia River Group Older alluvium	92	33	1959	—	490
18cba	93	I	A	Older alluvium	90	44	1964	—	550
21abc	122	D	A	Basalt of Columbia River Group	70	25	1961	—	527
21ddd	200	P	A	Older alluvium	—	83	1958	—	592
22ddc	170	P	A	Basalt of Columbia River Group	125	107	1958	—	612
27dac	553	P	P	do.	155	155	1950	—	630
33dbb	112	D	A	do.	91	30	1966	—	563
4N/29E-5da	770	I	—	do.	110	66	1953	—	560
8dcb	271	I	A	do.	112	60	1964	—	660
13dbd	527	I	P	Basalt of Columbia River Group Older alluvium	111	70	1954	—	712
18daa	262	I	P	Basalt of Columbia River Group Older alluvium	225	62	1954	−½	675
[1]32cac	300	P	A	Basalt of Columbia River Group	53	20	1959	—	580
	701	P	—	do.	53	15	1962	—	580
	778	P	—	do.	53	147	1965	—	580
5N/26E-34dbb	46	D	A	do.	14	3	1965	—	310
5N/27E-19cd	190	P	—	Older alluvium	—	—	—	—	310
19cd	65	D	A	Basalt of Columbia River Group	56	37	1964	—	310
5N/28E-10dad	777	P	P	do.	117	145	1952	—	377
17cab	536	P	—	do.	—	70	1953	—	280
19aaa	785	P	P	do.	170	115	1947	—	485
22bba	189	D	—	do.	8	7	1953	−1½	440
28acb	154	D	A	do.	30	40	1960	—	477
34dcd	177	D	A	Older alluvium Basalt of Columbia River Group	160	92	1963	—	530
1S/26E-1dad	70	I	P	Basalt of Columbia River Group	27	F	1957	—	1600

[1] Well deepened

[2] Use of water: I, irrigation; D, domestic or stock; P, public supply or industrial; U, unused

[3] Driller's log: A, available in U.S. Geol. Survey files; P, published in Water-Supply Paper 1620

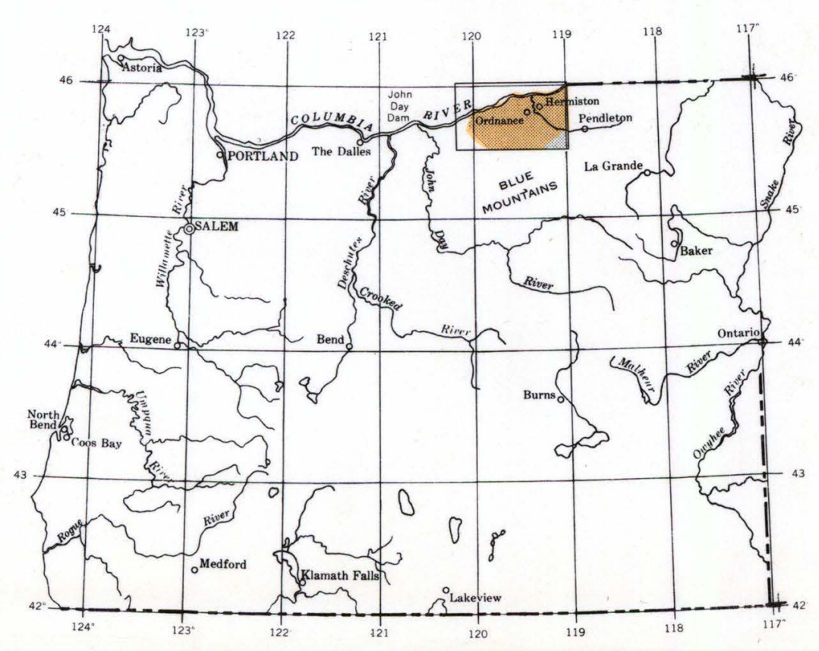
[4] Source of water: Formation reported to yield water to well or that affects water level of well. Tcr, basalt of Columbia River Group; Qoa, older alluvium

[5] Water level: F, flowing above land surface. Rate of change based on periodic measurements 1962–67

INTRODUCTION

This study was made at the request of and in cooperation with the Oregon State Engineer to study geologic and hydrologic conditions in the Hermiston-Ordnance area that may be related to recent declines in ground-water levels.

Hermiston, Ordnance, and surrounding areas lie within the Umatilla lowlands of north-central Oregon. (See index map.) Southward from the Columbia River the land rises along gentle slopes and low terraces to the low, rounded hills and small valleys at the base of the Blue Mountains. The climate of the region is mild and semiarid. Most of the precipitation occurs during late fall through spring and very little occurs in July and August. The population, about 10,000 in 1965, is concentrated in the towns of Hermiston, Umatilla, Irrigon, and Boardman. The economy is mostly rural. Large parts of the low hills are used for dryfarming of wheat and for grazing of sheep and cattle. Alfalfa and truck crops are grown in small irrigated areas in the lowlands.



INDEX MAP OF OREGON SHOWING LOCATION OF REPORT AREA

Distribution systems to supply irrigation water from the Umatilla River were built between 1905 and 1912. By 1936, these systems served 8,000 acres near Hermiston and 9,700 acres west of the Umatilla River. In addition, individual farmers irrigated a large acreage directly from Butter Creek and the Umatilla River.

Light industry, defense installations (including a U.S. Army ordnance depot, a U.S. Navy bombing range, and a rocket-testing range), and McNary Dam on the Columbia River 2 miles east of Umatilla contribute to the economy. Industry and shipping are expected to increase as a result of completion in 1968 of John Day Dam on the Columbia River, 35 miles west of Heppner Junction. Backwater from the dam extends upriver to McNary Dam.

GEOLOGY

Below 1,500 feet altitude, the low hills along the south edge of the area are underlain by Miocene and Pliocene basalt and by sedimentary deposits of Pliocene and Pleistocene age. Above 1,500 feet altitude, the hills are underlain by basalt only. The geology of the eastern half of the area as mapped by Hogenson (1964) was revised, and the geologic mapping was extended westward by the author. The rock units are discussed below in the order in which they would be penetrated by the drill in the area of principal ground-water development.

The older alluvium (equivalent to the glaciofluviatile deposits of Hogenson) lies mostly below 750 feet altitude, where much of it was deposited by the ancestral Columbia River. The coarser material was deposited when the river was swollen during warm intervals in the Pleistocene. There are some clay and silt layers at or near the base of the alluvium which may be lacustrine deposits formed when ice and debris dammed the river at constrictions downstream. The thickness of the alluvium in the flat areas averages 50 to 100 feet and attains a maximum of about 200 feet.

On the north slope of the Blue Mountains, fanglomerate of Pliocene age overlies the basalt between altitudes of 750 and 1,500 feet. The fanglomerate, which contains caliche in most exposures, is generally more indurated than is the alluvium and probably is correlative with the Dalles Formation (Newcomb, 1966). Only basaltic fragments have been noted in the fanglomerate, whereas the alluvium contains a small percentage of granitic and quartzitic pebbles and boulders transported from the upper Columbia River basin. As shown on the map, the fanglomerate includes thin deposits mapped by Hogenson as "glacial-lake sediments," which may be the source of the loess that in places veneers both the fanglomerate and the basalt. Because of its low permeability and position above the water table in many places, the fanglomerate is not regarded as a good aquifer.

Basalt of the Columbia River Group underlies all the area but, except near the river, it is generally overlain by alluvial materials at altitudes below 1,500 feet. The basalt may be several thousand feet thick, although only about a thousand feet has been penetrated by wells locally. The basalt is composed of separate flows, each as much as 100 feet thick. Each flow is commonly dense, hard, olivine basalt near the base and grades upward to softer, vesicular, and scoriaceous zones at the top. Gross permeability hydraulic conductivity of a flow is quite low in the vertical direction. Interlayers of clay or clay and tuffaceous sand as much as 100 feet thick constitute 4-30 percent of the total thickness of the Columbia River Group.

The basalt has been warped into the 160-mile-long Dalles-Umatilla syncline (Newcomb, 1967). The Columbia River follows the synclinal axis from Heppner Junction to Umatilla; the Hermiston-Ordnance area is on the south limb of this broad syncline. The dip in the southern part of the area averages about a hundred feet per mile (1°) to the north and flattens to 30 feet per mile in the northern half of the area.

The Service anticline as mapped by Hogenson (1964) is subsidiary to the Dalles-Umatilla syncline and extends from the Service Buttes northward across the Columbia River to Sillusi Butte. The anticlinal nature of the structure is not apparent throughout its length, but it has an eastward-dipping reverse fault at the base of the west limb and a fault at the base of the east limb. The faults were mapped from exposures and traced, where possible, beneath the alluvium with a portable magnetometer. The magnetometer surveys seemed to confirm relief on the basalt in places, but neither confirmed nor denied requirements for a fault (Andrew Griscom, oral commun., 1969). However, relief on the basalt is minimal beneath several profiles that exhibit magnetic anomalies.

A few northwestward-trending faults in the southern part of the area are evident in places where the basalt is exposed, are reflected somewhat in the topography, and are discernible on aerial photographs. Movement along the faults may be largely confined to the basalt; the alluvium and the exposed beds of the fanglomerate do not seem to be disrupted. Magnetometer surveys were not as useful here because some anomalies found do not necessarily indicate faulting.

A fault parallel to Butter Creek, tentatively suggested by Hogenson (1964, p. 41), was not confirmed by the magnetic data; however, the linearity of Butter Creek may be caused by an anticline in the underlying basalt west of the creek.

Topography and well data indicate that an anticline lies beneath a ridge 2 miles west of Hermiston Butte and parallel with the Service Butte anticline.

A depression in the basalt in T. 4 N., Rs. 26 and 27 E., is suggested by the log of well 4N/26E-25bcb (see well-numbering diagram for well-numbering system used in this report), which did not penetrate basalt at its maximum depth of 170 feet, and by the log of well 4N/27E-20cbc; the magnetic data are inconclusive. Well data and basalt outcrops help to define the structural depression in the vicinity of Hermiston.

The faults, even though they are oblique rather than normal to the dip of the basalt, divide the aquifers into compartments. The faults and the anticlines probably restrict ground-water movement. The gouge of most faults is fine grained and poorly permeable. Anticlines may also restrict movement and tend to form hydraulic divides between adjacent compartments.

GROUND WATER

The basalt of the Columbia River Group contains the most widespread aquifers in the area and is capable of yielding 1,000 gpm (gallons per minute) or more to most properly constructed wells. The area near Hermiston and the valleys of Butter Creek and the Umatilla River contain alluvial aquifers capable of yielding supplies adequate for domestic use. In much of T. 4 N., R. 27 E., the alluvium contains gravel that yields as much as 2,000 gpm to irrigation wells, but farther south and west the alluvium thins and is above the water table.

A few private irrigation wells have supplied ground water since the area was settled. However, beginning in the late 1950's, a substantial number of deep, large-capacity wells have been drilled. The deeper basalt aquifers in the central part of the area were first tapped in 1941 (Sceva, 1966, p. 6-8), when the Umatilla Army Depot was built at Ordnance, and development underwent a rapid increase in the late 1950's when wells were drilled to irrigate alfalfa. Similar development occurred in the Butter Creek area in the 1950's. Municipal and industrial wells were drilled at Hermiston, Umatilla, Irrigon, and Boardman during the same period; these wells are more widely spaced, and withdrawals are small compared with withdrawals from irrigation wells.

Drilling records (see table of selected well data), hydrographs, differences in water quality, and differences in head all indicate the existence of several independent or semi-independent hydraulic systems. To simplify analysis, the existence of three systems was considered; these systems or zones are based on depth. The shallow zone includes alluvial deposits and the uppermost basalt aquifers and is limited to a maximum depth of about 200 feet. The intermediate zone is limited to basalt aquifers only and extends to a depth of about 400 feet. The deep zone also is confined to basalt aquifers and includes depths below about 400 feet.

Because of the low vertical permeability of individual basalt flows, there is little or no vertical flow between zones under natural conditions. However, wells open to several zones have allowed water to move from one zone to another locally. Because so many wells are open to multiple zones, meaningful water-level or water-level-change maps cannot be prepared for different zones in the area.

In addition to the vertical separation into systems, faults and other geologic structures have produced areal compartmentation of the overall hydraulic system. Hydrologic evidence for this compartmentalization includes (1) flat water-level gradients, (2) differences in age of the water, (3) continuing water-level declines associated with pumping, and (4) known differences in head from place to place throughout the area.

Potentiometric-head relations within the area are varied and complex. In some wells heads increase with depth, in others heads decline markedly as wells are deepened. Heads in deep wells near the Columbia River are at or below river level, so that ground water cannot be discharged into the river. Throughout much of the deep zone, hydraulic gradients are very flat, demonstrating both the high transmissivity of the zone and the near-stagnant condition or lack of movement of water in the zone.

Some examples of the head relations include well 2N/27E-20daa, which has not been in production. This well went dry in 1968 when a new well in the same section was drilled to a depth of 1,103 feet; head of the deepest zone of the new well was 80 feet lower than that of the shallower zones.

The head in well 2N/27E-2daa in the valley of Butter Creek increased with depth; the well began to flow after drilling to more than 700 feet. At well 3N/28E-28cbb the head is about 80 feet below land surface in the zone above a depth of 400 feet, but the water level dropped to 280 feet below land surface (water-surface altitude about 430 feet above mean sea level) when the well was completed to 636 feet. Within the deep aquifers there seems to be no gradient northward from this well to Hermiston.

In the Ordnance area, downhole current-meter tests in wells 4N/27E-18cdb and 4N/27E-22cda showed no vertical flow (Sceva, 1966, p. 6), thus indicating no apparent head differences among the zones surveyed. However, southwest of Ordnance, a flowmeter test made in 1969 by staff of the Oregon State Engineer indicated downward movement of water from a shallow zone in a well.

The water-level observation network maintained by the State under cooperative agreement with the Geological Survey includes about 45 wells in the Hermiston-Ordnance area. Periodic measurements of most of the wells began in 1961. Water-level declines began when substantial pumping of ground water began, and rates of decline have increased as rates of withdrawal have increased. Beginning about 1960, water levels declined enough to concern farmers and water managers- and in July 1966, the Oregon State Engineer declared Tps. 3, 4, and 5 N., Rs. 26 and 27 E., a "critical ground-water area." A report recommended that drilling of wells deeper than 400 feet be discontinued (Sceva, 1966, p. 7-8).

Water-level changes typical of wells open to deeper basalt aquifers is shown by the hydrograph of well 4N/27E-18cdb (see hydrologic map), in which the water level has declined about 10 feet per year. In some of the deep wells the rate of decline increased in the late 1960's. In several wells, water levels have declined more than 20 feet in a single year.

Water-level changes vary with depth, area, and materials penetrated. Well 4N/26E-25bcb (see hydrologic map) is open to only 170 feet of alluvial deposits, and its water level has declined 1 foot per year. Well 4N/27E-22cda (see hydrologic map) is in a developed area and penetrates 170 feet of basalt, but it is open to both alluvial and basalt aquifers, and the average decline is 1½ feet per year.

Artesian levels have risen in well 1N/27E-24ddd. (See hydrologic map.) The well is not in a heavily pumped area and may be protected by structural barriers, but reasons for the rise are not known; possibly rubble and sediment in the well have moved from zones of high head to zones of lower head and sealed them.

The rise of water levels in well 4N/25E-9ac (see hydrologic map) apparently is caused by a good hydraulic connection (permitted by well construction and gravel at shallow depth) with the reservoir formed when the John Day Dam was completed in April 1968.

Seasonal fluctuations of water levels are evident in deeper wells, and the greatest fluctuations occur in wells with the greatest annual declines. Lowest levels are in late summer, near the end of the season of substantial pumping for irrigation. After pumping diminishes, water levels in individual wells rise as water moves laterally in aquifers to fill the potentiometric depressions. The fluctuations are due to withdrawal of ground water rather than to seasonal recharge. If the fluctuations were caused by seasonal distribution of rainfall or streamflow, a correlation would be most evident in aquifers with relatively good vertical permeability and a shallow water level, such as well 4N/26E-25bcb; however, this well shows no seasonal fluctuations. Probably the intermediate and deep aquifers receive no local recharge from precipitation.

That contemporary precipitation patterns are not the cause of declining ground-water levels is shown by U.S. Weather Bureau records for Hermiston and Heppner (16 miles southwest of Pine City). The graphs of precipitation and cumulative-departure show a rising trend in precipitation from 1940 to 1964, when ground-water levels began to decline.

On the graph showing water-level changes and thickness of basalt penetrated by wells, none of the wells that penetrate less than 400 feet of basalt has a water level that declined more than 5 feet per year, but most wells that penetrate more than 400 feet of basalt have water levels that declined at least 5 feet per year. Wells known to penetrate less than 200 feet of basalt or to produce only from the shallow zone commonly show declines of less than 4 feet per year.

In 1966, ground-water rights for irrigation were in effect for about 5,000 acres in the most heavily developed area (T. 4 N., Rs. 26 and 27 E., and the north half of T. 3 N., Rs. 26 and 27 E.). Assuming that the rights were fully exercised, 15,000 acre-feet of ground water was withdrawn. On the basis of depth and construction of the wells, 6,000 acre-feet would have been pumped from the shallow zone, 1,000 acre-feet or more from the intermediate zone, and 8,000 acre-feet or less from the deep zone.

Several times as much water was withdrawn from the deep zone as from the intermediate zone, and this may account for differences in the rates of decline of water levels in individual wells. However, the rate of seasonal recovery of wells in the Ordnance area suggests that the deep zone has greater transmissivity than does the intermediate zone. If equal quantities of water were pumped from the intermediate and deep aquifers, the intermediate zone could be expected to show the greater rate of water-level decline.

Analysis of pumping tests or other parameters to determine values of transmissivity is dependent on a number of assumptions. Two that may be critical for this area are that (1) the aquifers are of infinite areal extent, and (2) transmissivity is constant at all times and places in the aquifer system. For most hydrologic systems the fact that field conditions do not meet the ideal requirements either can be compensated for or safely ignored. In aquifers with relatively high values of transmissivity and low storage coefficients, such as in the basalt of this area, hydraulic effects extend to great distances. Eventually, pumping effects will reach boundaries or restrictions in the system, but often not until after the period of conventional pumping tests. In addition, as zones are dewatered transmissivity will be reduced. For these reasons, predictions made from pumping tests are likely to underestimate water-level declines; pumping-test results should be used cautiously if they are used at all.

The consulting firm of Cornell, Howland, Hayes & Merryfield made 12-hour pumping tests of two wells (4N/28E-11cca and 4N/28E-11cac) for the city of Hermiston. Using data presented in the consultant's report, the author computed the transmissivity in the basalt to be 9,000-17,000 ft^2 per day (67,000-130,000 gpd per ft). Specific capacity of these wells is 11 to 13 gpm per foot of drawdown compared with an average of 50 to 60 for wells in the Ordnance area that produce 800 gpm or more from basalt. On the basis of the reported specific capacities, basalt in the Ordnance area would have a transmissivity of at least 20,000 ft^2 per day (Bentall, 1963, p. 338-340), and possibly as high as 70,000 ft^2 per day.

The table below shows seasonal drawdown (decline of the water level during the pumping season) of four deep wells at the Ordnance depot. Despite significant differences in reported specific capacity and volume of water withdrawn, water levels in the individual wells have responded similarly. These responses must be due to pumping from other wells within their hydraulic compartment; withdrawals from these depot wells are small compared to withdrawals from irrigation wells.

Well	Specific capacity, in gpm per ft of drawdown	Well production in 1966, in acre-feet of water	Net decline of water level, 1966-67, in feet	Net decline of water level, 1963-67, in feet	Seasonal drawdown (feet)						
					1960	1961	1962	1963	1964	1965	1966
4N/27E -5aba	18	8.31	9	24	11	21	25	27	28	28	40
5baa	87	1.62	9	20	--	--	--	25	29	32	40
18cdb	290	20.35	8	35	11	20	22	27	[1]30	30	40
19baa	23	17.17	10	26	--	--	24	27	34	38	39

[1] Estimated.

In these four and other wells that are not pumped heavily (the combined average pumping rate of the wells in the table was less than 30 gpm during 1966), the seasonal drawdown of water levels may be proportional to the total volume of water withdrawn from local aquifers that are open to the wells. The size of the area affected by the response of a well or group of wells is unknown but is probably no larger than the area bounded by major structural barriers in the aquifers.

Although Willow Creek, Butter Creek, Umatilla River, and Columbia River are within or border the area, no direct hydraulic connection between these streams and ground-water bodies in the basalt aquifers was demonstrable; therefore, streamflows are not analyzed in this report.

QUALITY OF WATER

Almost all ground and surface water of the area is of calcium, sodium calcium, or sodium bicarbonate type. Dissolved solids of the Columbia River range from about 70 to 150 mg/l (milligrams per liter), depending on the rate of discharge; dissolved solids in other surface and ground waters commonly range from 200 to 400 mg/l.

Some apparent general trends were noted in ground-water quality in the study area:

Change with increasing depth of aquifer

Bicarbonate	Decrease
Hardness	Decrease
Sulfate	Decrease
Percent sodium	Increase
Fluoride	Increase
Dissolved solids	Slight decrease
pH	Slight increase
Temperature	Increase

The ground water is suitable for most uses, although hardness of water from shallower aquifers is greater than is preferred for domestic use. Sodium-adsorption-ratio (SAR) of some of the deeper water is high for irrigation use; but, because soils are permeable, no deleterious effects have been noted. Concentrations of iron in excess of 0.2 mg/l have not been reported for any wells. Some of the deeper aquifers have concentrations of fluoride as high as 2.0 mg/l. The results of ground-water analyses are shown in the table entitled "Chemical analyses of ground water."

The trilinear diagram shows the relationship and clustering of points representing water analyses of the several aquifers. It was not necessary to show the total anion field because all the water is high in percent bicarbonate; the scale of the remaining field has been expanded. The natural grouping of the chemical analyses can be examined when the diamond field is divided into the A, B, and C areas shown. Each area contains analyses characteristic of particular water sources:

Type A—Surface water, alluvial aquifers, and the uppermost basalt aquifers.
Type B—Intermediate-depth basalt aquifers that are penetrated less than 350 feet by the sampled well.
Type C—Deep basalt aquifers that are penetrated more than 350 feet by the sampled well.

Most apparent exceptions to the above classifications can be explained by well construction that allows production of shallow water from a deep well, or by upward leakage of water along a fault. Although most of the deeper wells are open to both intermediate and deep basalt aquifers, the analyses fall into distinct B and C groups rather than being a gradational mixture of the two types. This suggests that the deep aquifer usually dominates in the production of water from wells open to more than one aquifer.

Data are few, but the figure of water-level changes and basalt thickness shows that no wells that produce type A or B water have water-level declines of more than 5 feet per year.

CARBON-14 DATING

Three wells representing different aquifer depths were sampled for carbon-14 dating of the bicarbonate in the ground water (Feltz and Hanshaw, 1963). The dating was done under the direction of Meyer Rubin at the Geological Survey Laboratory in Washington, D. C., and the results are summarized in the table below.

RADIOCARBON AGES OF GROUND WATER

Aquifer represented	Interval open to well (depth in feet)	Type of water	Well number	U.S. Geol. Survey Lab. No.	Apparent age (years)
Shallow	30-70	A	1S/26E-1dad	W-2112	Modern
Intermediate	256-453	B	4N/27E-8dda	W-2090	6,700
Deep	200-950	C	3N/26E-5cbd	W-2092	27,290

To determine if the atmosphere rather than the old carbon in the formation were the probable source of the bicarbonate in the water, the shallow and deep samples were analyzed for content of carbon-13, a stable isotope. The results indicate that at least 70 percent of the carbon in the deep water and at least 90 percent of the carbon in the shallow water is of atmospheric origin. Accordingly, no corrections were made to the carbon-14 ages.

The shallow sample, from well 1S/26E-1dad, has a carbon-14 activity consistent with a "modern" age; it was last exposed to the atmosphere rather recently, possibly since 1950.

The intermediate sample, from well 4N/27E-8dda, has an indicated age of 6,700 years. The area of recharge and travel path of water to well 4N/27E-8dda is not known. Vertical permeability of the basalt is low, and the closest area where permeable horizontal zones might be shallow enough to be recharged directly is in the vicinity of Butter Creek, about 8 miles away. If recharge occurs in that area, the average rate of movement indicated would be about 6 or 7 feet per year.

The semi-independence of the basalt aquifers and the large differences in hydraulic head with depth in some areas make it difficult to determine the probable travel path of the water from the deep zone. The deep aquifers are not exposed within any reasonable distance upgradient, if they are exposed at all. Any recharge they receive may be partly by slow vertical movement through fractured zones in the basalt.

The apparent age (27,290 years) of water in the deep aquifer may be a minimum value because the sample may have contained some water from the intermediate-depth zone. The sampled well produces mostly from below 500 feet, but is also open to the intermediate zone, as are all deep wells in the area.

Because the well yielding the 27,290-year sample is open to all depth zones, the water obtained may have been a mixture containing even older water. A sample with as little as 7 percent of intermediate-depth water (6,700 years) mixed with water of infinite apparent age would have the same carbon-14 activity as the sample that was dated as 27,290 years. Because of the exponential decay rate of carbon-14, about 30,000 years is the limit of dependable ages for ground water that can be determined by that method.

CONCLUSIONS

Ground water in the deeper basalt aquifers is receiving little recharge. The complex head relations demonstrate the vertical separation and lateral compartmentation of aquifer units, and the water-level fluctuations indicate that the intermediate and deeper zones receive no recharge from local precipitation. Except for the interchange of water through wells open to two or more zones, movement of water in the two deeper zones may be largely in response to pumping effects; that is, water moves in the aquifers toward pumping wells to supply the water being withdrawn or to level out water levels after pumping is stopped. These aquifers in the Hermiston area do not exhibit the classic ground-water circulation pattern-from areas of recharge through an aquifer system to areas of natural discharge.

The deeper aquifers are cut off from areas of potential recharge by the geologic features that produce aquifer compartmentalization. The flat water-level gradients in these zones and the continual decline of water levels in wells penetrating them suggest that several of these aquifer systems receive no recharge (except leakage down uncased wells). Water pumped from them is largely or entirely ancient water now being removed from storage; the greater the pumpage, the greater the ensuing water-level declines. The lowering of water levels in the basalt is not likely to allow a significant increase in the rate of natural recharge.

Due to differences in specific yield, a 10-foot water-level decline in the basalt represents less water removed than does a 1-foot decline in the alluvium. Specific yield is 20-30 percent in the alluvium and 1-2 percent in unconfined basalt aquifers. The large decline in the basalt is presently more significant than is the smaller decline in the alluvium because it results in (1) increased pumping costs due to the additional lift required and (2) increased depths to which wells must be drilled or deepened: but most of all because it suggests that recharge to basaltic aquifers is small.

The basalt aquifers might be recharged artificially with surface water by injection into new or existing deep wells (Foxworthy and Bryant, 1967). The most convenient and dependable source is Columbia River water, either from the reservoir behind McNary Dam (normal pool altitude 340 feet) or the reservoir behind John Day Dam (normal pool altitude 268 feet). If a reservoir is built at the proposed Paterson Ridge site in Washington (Young, 1967), water might be transferred across or beneath the Columbia River from a pool altitude of 450-600 feet.

However, if surface water is to be used to resolve local water problems, direct use of the water might be more economical than using wells to recharge the aquifers and later lifting the water out of the aquifers for use. Some sites within the area may be suitable for small reservoirs for short-term management of surface water.

REFERENCES

Bartholomew, W. S., and DeBow, Robert, 1967, Ground-water levels, 1966: Oregon State Engineer, Ground Water Rept. 12, 122 p.

Bental, Ray, compiler, 1963, Methods of determining permeability, transmissibility and drawdown: U.S. Geol. Survey Water-Supply Paper 1536-I, p. 243-341.

Feltz, H. R., and Hanshaw, B. B., 1963, Preparation of water sample for carbon-14 dating: U.S. Geol. Survey Circ. 480, 3 p.

Ferris, J. G., Knowles, D. B., Brown, R. H., and Stallman, R. W., 1962, Theory of aquifer tests: U.S. Geol. Survey Water-Supply Paper 1536-E, 174 p.

Foxworthy, B. L., and Bryant, C .T., 1967, Artificial recharge through a well tapping basalt aquifers at The Dalles, Oregon: U.S. Geol. Survey Water-Supply Paper 1594-E, 55 p.

Hogenson, G. M., 1953, Geology of the Boardman Bombing Range Reservation, Boardman, Oregon: U.S. Geol. Survey open-file rept., 5 p.

——1964, Geology and ground water of the Umatilla River basin, Oregon: U.S. Geol. Survey Water-Supply Paper 1620, 162 p.

Meyers, J. D., 1966, A plan for development of the Oregon mid-Columbia River waterfront: Oregon Dept. Commerce, 122 p.

Newcomb, R. C., 1961, Storage of ground water behind subsurface dams in the Columbia River basalt, Washington, Oregon, and Idaho: U.S. Geol. Survey Prof. Paper 383-A, 15 p.

——1966, Lithology and eastward extension of the Dalles Formation, Oregon and Washington: U.S. Geol. Survey Prof. Paper 550-D, p. D59-D63.

——1967, The Dalles-Umatilla syncline, Oregon and Washington: U.S. Geol. Survey Prof. Paper 575-B, p. B88-B93.

Sceva, J. A., 1966, A brief description of the ground-water conditions in the Ordnance area, Morrow and Umatilla Counties, Oregon: Oregon State Engineer, Ground Water Rept. 11, 43 p.

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

Young, L. L., 1967, Paterson Ridge pumped-storage site, Washington: U.S. Geol. Survey open-file rept., 37 p.

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