Geology and ground-water resources of the Duck Lake area, Okanogan County, Washington. This study was initiated to determine the extent of the Duck Lake ground-water area as requested by the Central Operations Division of the Department of Ecology. Report was prepared by Peder Grimstad of the Comprehensive Investigations and Studies Division and Eugene F. Wallace of the Central Operations Division, Department of Ecology, Olympia, Washington, December, 1971.

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PURPOSE AND SCOPE OF THE INVESTIGATION

The purpose of this investigation was to determine the extent of the Duck Lake ground-water area based chiefly on geohydrologic conditions and to recommend a tentative perimeter description based on definable geographic designations and/or geologic features which can be identified with certainty in the field. The report was also to include a brief resume of the geohydrologic conditions of the area along with sufficient support data to justify the recommendations.

Prior work in the Duck Lake area was essentially limited to a study begun in March of 1958 by E. F. Wallace, co-author, of the Division of Water Resources of the Washington State Department of Conservation. This resulted in a preliminary unpublished report which was based upon field investigation, well measurements, well records and miscellaneous information available from the Department files.

In September of 1970, Dr. George Maddox of the Department of Ecology, made a well survey in conjunction with a refraction seismic survey conducted by the Bureau of Reclamation of the Department of Interior. This was followed in April of 1971 with experimental refraction seismic work by Department of Ecology personnel. In May and June of 1971, Peder Grimstad, co-author, spent a total of five days in field reconnaissance of the surficial geology and a canvass of selected wells.

LOCATION AND TOPOGRAPHY

The general area of investigation (see Plate 1) covers about 20 square miles and is bounded on the west by the Omak-Conconully road, on the north by Johnson Creek, on the east by U.S. Highway 97, and on the south by the prominent escarpment extending from Ross Canyon to Coleman Butte. The area is immediately north of Omak and is readily accessible by U.S. Highway 97 and an extensive network of hard surfaced and graveled roads.

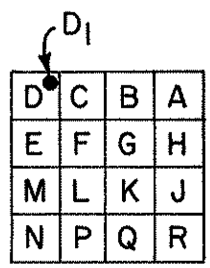
The specific area of interest includes Sections 1, 2, 10, 11, 12, 13, 14, 15, 22, 23 and 24 of T. 34 N., R. 26 E. It consists of an upland bench which slopes gently southeasterly to an escarpment above the Okanogan River on the east and south, and abutts the hills on the west and north. The bench descends from an elevation of about 1,330 feet near the hills to about 1,200 feet at the edge of the escarpment and is about 400 feet above the Town of Omak.

There is no discernible surface drainage from the bench and the only naturally occurring surface water is in the kettle-type lakes. Numerous other kettles, and outwashed channels emanating from the valley now occupied by Johnson Creek, are discernible throughout the area.

The climate is semi-arid with the annual precipitation ranging from 4.79 inches in 1929 to 22.32 inches in 1948. The mean annual precipitation for the period from 1930 through 1959 is 12.20 inches.

WELL NUMBERING SYSTEM

The locations of wells are shown according to the rectangular system for sub-division of public land, indicating township, range, section and 40 acre tract within the section. An example is the well numbered 34/26-11D1 owned by Emmet Smith. The part preceding the hyphen indicates successively the township and range (T. 34 N., R. 26 E.) north and east of the Willamette baseline and meridian. The first number after the hyphen indicates the section (11) within that township and the letter (D) gives the 40 acre subdivision of the section as shown in the diagram. The last number (1) is the serial number of the well in that particular 40 acre tract and is the first well recorded there. The second well recorded would have the number 34/26-11D2.



GEOLOGY

The geology of the Duck Lake area is rather complex; however, for the purpose of this study it is only necessary to consider two general units based upon their ability or lack thereof, to transmit and store water (see Plate 1).

One unit consists of a complex assemblage of metamorphic and igneous rocks which has very low permeability and porosity and serves as an effective barrier to the downward migration of ground water.

Overlying these rocks is the second unit which consists of glacial and fluvial deposits of clay, silt, sand and gravel of Pleistocene-Holocene age.

These are the youngest deposits in the area and, as a unit, is the only one capable of storing and transmitting water. This unit is unconsolidated and generally lacks discernible bedding. However, present topography and scattered outcrops suggest a northwesterly source for the outwash waters. Undoubtedly melt water from wasting glaciers in the Cascades which flowed down the present day Johnson Creek drainage played an important part in the final phase of erosion and deposition in the area. The outcrops of silt and clay in the escarpment extending from Coleman Butte westerly to Ross Canyon indicate deposition in a low energy environment such as a lake or water behind a river bar.

Historically, we can begin with an interval of erosion after the extrusion of the youngest rocks (volcanic flows) of the bedrock sequence. This was followed in Pleistocene time by the advent of an extensive ice sheet pushing down from Canada and covering all but the highest peaks. Upon recession of the continental ice, sands and gravels resulting from the glaciation were re-worked, transported and laid down by outwash streams flowing from the melting and receding ice. Lakes were formed largely because of ice damming and in these calm waters silts and clays were deposited. In places, large blocks of ice were engulfed by the outwash material and upon melting of the ice, depressions or kettles were left which presently are filled with water where these extend below the ground water table (Duck, Proctor, and Fry Lakes). Similar depressions which do not intersect the water table, occur throughout the area. Large quantities of water flowing from melting upland glaciers to the west were the final modifying force and left the terrain in the area of interest essentially as it is today.

GROUND WATER

The principal aquifer in the Duck Lake area consists of sands and gravels lying unconformably on bedrock. On the north and west sides it is limited by bedrock exposures. On the south side, i.e. from the center of Section 22, T. 34 N., R. 26 E., eastward to Colemen Butte, the movement of ground water is greatly impeded by a buried ridge of bedrock and the presence of impermeable clays and silts which crop out east and west of Robinson Canyon. These are believed to be the "quicksand" reportedly encountered in wells drilled along or near Miller Road which runs easterly through the center of Section 23. There are scattered bedrock exposures north of Coleman Butte to the north line of Section 13 which indicate the probable existence of another buried ridge of bedrock. This would form at least a partial barrier to the eastward flow of ground water. The nature of the impeding barrier believed to be present and extending from the north line of Section 13 northward to bedrock exposures in Section 35 is unknown on the basis of surface geology. However, the increase in depth to the water table (increase in the hydraulic gradient) indicates a decrease in the permeability or the thickness of the aquifer. This condition is comparable to that existing along the southeast side and it is assumed that a similar silting out or thinning of the aquifer takes place along the northeast side.

In summary, the boundaries of the Duck Lake aquifer are well established on the west and northwest sides. The southeasterly boundary is not well defined; however, the 1210 foot water-level contour line represents the southeasterly extent of a relatively low hydraulic gradient and the beginning of a generally silty aquifer with low well yields. At the north line of Section 13, the boundary is continued eastward to the 1200 foot contour which is followed to the east quarter corner of Section 12. The extension of the boundary from this point is based upon water levels in widely spaced wells. As there is no data to establish where the increase in hydraulic gradient begins northeast of well 11 D1, the boundary has been drawn about half the distance between wells 11 D1 and 1 Q1 through the northwest corner of Section 12. From this point it is extended northward along the west line of Section 1 to bedrock near the southeast corner of Section 35, T. 35 N., R. 26 E., thence southwesterly across the south line of Section 35 along a ground-water divide as indicated by water level data. The approximate boundary then follows Johnson Creek and extends to bedrock near the southwest corner of the Section 3, the point of beginning of the rather well defined northwest boundary.

On the basis of the above data, the land surface areal extent of the Duck Lake aquifer is believed to be about 3500 acres.

The aquifer thickness has been established at scattered points by drilled or dug wells which have penetrated to bedrock, and from the refraction seismic surveys conducted in 1970 and 1971. Based on these scattered data and the knowledge that the old bedrock surface is rather uneven (see Plate 1), an average thickness of 40 feet for the aquifer is thought to be a realistic estimate. The specific yield, which is the ratio of the volume of water a saturated rock will yield, by gravity, to the total volume of the rock, was assumed to be 15%, which is conservative for a good sand and gravel aquifer. Using a surface area of 3500 acres and the preceding figures, the available storage capacity of the Duck Lake aquifer is calculated to be 21000 acre feet. To utilize this quantity of water would require a well deepening program as most of the existing wells are not of sufficient depth to withdraw water from the entire thickness of the aquifer. Data from 67 wells measured in 1958 - 1960, indicate that the average penetration of the aquifer was 16 feet. Using this thickness, an areal extent of 3500 acres and a specific yield of 15%, the presently available capacity is about 8400 acre feet.

In summary, the available storage capacity of the Duck Lake aquifer area ranges from a conservative 8400 acre feet to a probable 21000 acre feet.

AQUIFER RECHARGE AND DISCHARGE

On the basis of meteorological data which are available from the McFarland weather station located within the area of interest, direct precipitation is of minimal importance in recharge of the unconfined Duck Lake aquifer. It appears possible that considerable ground water enters the aquifer from the Conconully Valley, i.e. from the northwest across Section 10. This is indicated by the water table contours which show a southeasterly ground-water flow and by preserved stream channels created by glacial melt water which flowed from the northwest. The latter evidence points to the existence of an old stream bed which now serves as a conduit for the transmittal of ground water to the aquifer. In addition, there is artificial recharge by the Okanogan Irrigation District and recharge incidental to irrigation of the project lands by water from Salmon Lake and Conconully Reservoir.

In years when surplus run-off water is available, the Okanogan Irrigation District diverts water into Duck Lake from Salmon Creek and Johnson Creek. Duck Lake is a ground-water lake in that its waters commingle with the ground water of the Duck Lake aquifer. Consequently, any recharge water put in Duck Lake also recharges the surrounding ground-water body.

The Okanogan Irrigation District recharged and pumped from Duck Lake under the schedule shown below during the years from 1958 to 1971.

YEAR	RECHARGE (ACRE FEET)	DISCHARGE (ACRE FEET)	YEAR	RECHARGE (ACRE FEET)	DISCHARGE (ACRE FEET)
1958	2960	?	1965	1800	2300
1959	3480	?	1966	1700	2850
1960	1980	?	1967	3550	0
1961	2600	0	1968	1854	0
1962	1700	2000	1969	2128	0
1963	2400	0	1970	1650	2224
1964	1700	2120			

Recharge incidental to the irrigation of project lands within the Okanogan Irrigation District is an important secondary source of recharge to the Duck Lake aquifer. In years of normal precipitation, most of the project lands are irrigated with water from Salmon Lake and Conconully Reservoirs. The water is released at the reservoirs and flows down Salmon Creek to a point in Section 31, T. 34 N., R. 26 E. where it is diverted by canal to serve district lands in the Duck Lake area as well as lands outside the report area. Most of the irrigation water that is not taken up by evaporation or consumed by the crops percolates down to the water table.

Discharge from the aquifer occurs through springs and seeps along the south and east sides of the area; however, this is believed to be minor. Only one spring was seen during the five day field reconnaissance in 1971. As indicated by water table contours, ground water moves southeasterly and northeasterly and escapes from the area of interest. Further, evapotranspiration occurs where the ground-water table is shallow. The remaining discharge is because of withdrawal by wells. This quantity is variable depending upon the program of the Okanogan Irrigation District. Presently about 670 acres are covered by primary ground-water rights in the area. Figuring an application of 4 acre feet per year, the annual withdrawal would be about 2680 acre feet assuming all rights were being used and the district was obtaining all its required water from surface water sources. Following years of below normal precipitation, the demands on the aquifer are greatly increased because during these periods the district pumps from Duck Lake, and many wells with supplementary rights are utilized.

CONCLUSIONS

The Duck Lake area is underlain by one aquifer (Duck Lake aquifer) which is in direct continuity with the surface waters of Duck Lake, Frye (Loon) Lake and Proctor Lake. The Duck Lake aquifer, composed of glacially derived sand and gravel of Pleistocene age, has an areal extent of over 3500 acres and is generally bounded by bedrock and/or silts and clays of low permeability on all sides, but it is not thought to lie in a perfect basin; both subsurface recharge to and discharge from the aquifer exist.

The specific yield of the aquifer has been estimated to be between 8400 and 21000 acre feet assuming the aquifer is fully recharged. The ground-water conditions in the Duck Lake area are not natural in that the Duck Lake aquifer is artificially recharged by water from Salmon and Johnson Creeks as well as receiving water incidental to the irrigation of district lands by water from Salmon Lake and Conconully Reservoirs. About 2680 acre feet per year are withdrawn when all primary ground-water rights are in use and the district's needs are fulfilled from outside of the basin. The demands on the aquifer increase markedly, however, when the outside supply becomes inadequate and the district pumps from Duck Lake and supplemental ground-water rights are exercised.

The geohydrologic boundary of the Duck Lake Aquifer is shown on Plate 1.

RECOMMENDATIONS

Based on this report and additional back-up support data, it is recommended that the following perimeter description be strongly considered by the Department of Ecology in establishing an area or sub-area designation for the Duck Lake aquifer: Beginning at the west quarter corner of Sec. 23; thence northeast through the north quarter corner of Sec. 23 and east quarter corner of Sec. 14 to the north quarter corner of Sec. 13; thence east to the northeast corner of Sec. 13; thence north to the east quarter corner of Sec. 12; thence northwest to the southeast corner of Sec. 2; thence north to the northeast corner of Sec. 2; thence west to the north quarter corner of Sec. 2; thence southwest through the west quarter corner of Sec. 2 to the south quarter corner of Sec. 3; thence west to the southwest corner of Sec. 3; thence south along the west line of Sec. 10 to the "bedrock" exposure; thence southeasterly along the "bedrock" to the south quarter corner of Sec. 10; thence south 1320 feet; thence west 1320 feet to the center of the NW¼ of Sec. 15; thence south 3960 feet to the south line of Sec. 15; thence east to the south quarter corner of Sec. 15; thence southeast to the point of beginning.

LIST OF SELECTED WELLS - DUCK LAKE AREA

OWNER	LOCATION	DEPTH OF WELL	DEPTH TO WATER	DATE OF MEASUREMENT	ALTITUDE OF WELL COLLAR	ALTITUDE OF WATER SURFACE
Frank Nilles	35.26.35L_1	80[r]	37.45	5/26/71	1290	1252.55
" "	" " 35P_1	-	53.78	5/26/71	1310	1256.22
Unknown	34.26.1 Q_1	-	147.05 146.18	6/16/71	1290	1143.––
Ralph Martin	" " 2 C_2	97[r]	62.65[a]	5/26/71	1300	1237.35
Gene Smith	" " 2 L_1	118.4	99.50[a]	5/26/71	1318	1218.50
Unknown	" " 10F_1	-	52.76	5/27/71	1300	1247.24
K. D. McKenzie	" " 10K_1	53	24.65	5/27/71	1267	1242.35
Emmet Smith	" " 11D_1	113	83.95[a]	5/26/71	1333	1249.05
Omak Airport	" " 11H_1	-	58.65[a]	5/26/71	1300	1241.35
" "	" " 11H_1	-	83. - 78.7	6/15/71	1300	1219.––
Unknown	" " 12A_1	-	117.8	5/26/71	1220	1102.20
Unknown	" " 12A_2	-	90.48	5/26/71	1215	1124.52
Christoph	" " 12J_1	17	10.48[a]	5/26/71	1215	1204.52
Munn	" " 12K_1	-	51.65	6/16/71	1270	1218.35
O'Dell	" " 12H_1	17.6	11.95	5/26/71	1215	1203.05
Gene Smith	" " 12M_1	-	80.00[a]	5/26/71	1300	1220.00
G. Robins	" " 12N_1	80	58.28	5/26/71	1274	1215.72
Lester Nelson	" " 12Q_1	73	60.55	5/26/71	1275	1214.45
Rawley Fawkes	" " 13B_1	-	46.20	5/26/71	1250	1203.80
Mark Bullock	" " 13C_1	125	60.87	5/26/71	1273	1212.13
Wm. Walters	" " 13C_2	97	62.90	5/26/71	1273	1210.10
Roy Taylor	" " 13M_1	67	66.45	5/26/71	1260	1193.55
Grace Bell	" " 14B_1	-	58.45	5/25/71	1283	1224.55
George O. Brown	" " 14G_1	-	43.60	5/27/71	1260	1216.40
Unknown	" " 14L_4	-	29.70	5/27/71	1250	1220.30

TABLE 1

OWNER	LOCATION	DEPTH OF WELL	DEPTH TO WATER	DATE OF MEASUREMENT	ALTITUDE OF WELL COLLAR	ALTITUDE OF WATER SURFACE
Unknown	34.26.14N_1	22	7.40	5/27/71	1225	1217.60
W. A. Stivers	" " 14N_3	22	2.77	5/27/71	1225	1222.23
Chas. Kalamia	" " 14N_4	48.7	26.18	5/27/71	1250	1223.82
Wm. F. Carter	" " 14P_1	50.5	12.28	5/27/71	1235	1222.72
Floyd Utt	" " 14R_1	73.5	71.50	5/25/71	1250	1178.50
Harold Torrence	" " 15H_1	62.5[r]	40.00	5/27/71	1270	1230.00
" "	" " 15H_2	-	37.00	5/27/71	1270	1233.00
P. D. George	" " 15J_1	49.5	33.04	5/27/71	1263	1229.96
W. F. Butler	" " 15K_1	38.8	27.90[a]	5/27/71	1257	1229.10
Ronald Shelton	" " 15Q_1	45.7	11.50	5/27/71	1237	1225.50
Chas. Riibe	" " 22A_3	27	10.70	5/27/71	1230	1219.30
" "	" " 22A_4	-	8.24	5/27/71	1228	1219.76
John Stalder	" " 22A_5	23	19.38	5/27/71	1238	1218.62
- McFarland	" " 22A_6	25	8.50	5/27/71	1226	1217.50
Rose McCormick	" " 22F_1	48.5	36.90	5/28/71	1282	1245.10
- Whiteley	" " 22G_3	20	1.80[a]	5/28/71	1224	1222.20
Unknown	" " 22J_2	-	22.40[a]	5/28/71	1230	1207.60
Unknown	" " 22K_3	-	15.50	5/28/71	1242	1226.50
Unknown	" " 22P_3	-	25.57	5/28/71	1275	1249.43
Ed Swallow	" " 23A_1	87.6	72.65	5/26/71	1245	1172.35
Paul Brantner	" " 23C_1	36.5	35.40	5/27/71	1250	1214.60
Dean Carlton	" " 24D_1	80	79.00	5/26/71	1255	1176.00
Unknown	" " 26C_1	350	214.35	6/15/71	1040	825.65
Unknown	" " 26D_1	-	28.45	6/15/71	1080	1051.55
Unknown	34.27.18D_1	-	30.00	5/26/71	1183	1153.00

Symbols: "a" - Wells pumping during measurement.
"r" - Reported depth.