KGS
OF
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ASSUMED EFFECT OF CLINTON RESERVOIR

ON

THE TONGANOXIE SANDSTONE AQUIFER

by

Maurice C. Crook

September 1971

Dr. Hilpman Geology 303

ASSUMPTIONS AND RECOMMENDATIONS

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In general the top of the Tonganoxie sandstone slopes from southwest to north and northwest. The base of this sandstone slopes in a similar manner except for two features of variance. Slope to the north is less steep than is that of the surface and the two meet in a pinch out line running westward from the area north of Lawrence. In the Overbrook recharge area the base of the sandstone dips downward to the southwest in an embayment apparently following an erosional lobe of the pre-Tonganoxie stream channel. In effect these factors create two low groundwater reservoirs with base elevation at the 650 foot contour with an east-west basal ridge separating them a hundred feet higher in the column.

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Lone star Lake in theory may be used as an example for partial check of the hypothesis. This lake was constructed in depression years and predates the development of the Tonganoxie well field. Only one well of record tapped the Tonganoxie as early as 1940 and that was a salty well in the city of Lawrence. There are few wells in the immediate area of Lone Star. One well near the lake and one about four miles down slope show exceptionally low mineralization. The remaining wells conform to their position down slope. As a result the evidence is inconclusive. With an elevation of about 950 feet Lone Star is 75 feet higher in the geologic column than Clinton and of relatively small area. It lies north of the Ireland limits and perhaps there is little hydraulic connection with the Tonganoxie.

In conclusion we may predict quality changes in the over-all well field. Most will be beneficial. Some will be detri-mental. Of the latter few are likely to prove critical.

A REVIEW OF SELECTIVE LITERATURE

COVERING

THE TONGANOXIE SANDSTONE AQUIFER

IN THE CLINTON RESERVOIR

AREA OF INFLUENCE

by

MAURICE C. CROOK

A PAPER SUBMITTED TO DR. PAUL L. HILPMAN

TO FULFILL AN ASSIGNMENT FOR GEOLOGY 303

AUGUST 1971

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ABSTRACT

A flood control and conservation reservoir to be constructed in western Douglas and eastern Shawnee Counties in Kansas will be superimposed over a lobe of the Tonganoxie sandstone aquifer. This underground reservoir supplies water to many farms downstream along the Wakaruse River valley.

The Tonganoxie aquifer curves in a broad arc from northeast to southwest across Douglas County extending into Franklin and Osage Counties. The Ireland sandstone constitutes a second aquifer trending east to west across southern Douglas and northern Franklin Counties. It is superimposed over and in hydraulic contact with the Tonganoxie in the southwestern sector of the study area. Largely fed by the Ireland the Tonganoxie forms an artesian aquifer sloping down dip to the northwest and down grade northeastward to outcrop in northeastern Douglas County.

At the surcharge area beneath the Ireland the Tonganoxie supplies a good flow of acceptable water. It is moderately soft, but somewhat saline. From this area the Town of Overbrook obtains its water supply.

At the northeastern terminus the Tonganoxie is breached by the Wakarusa River and the aquifer attains partial water table status. The outcrop vicinity serves as a recharge area

exerting westward artesian pressure. The two artesian slopes meet south and southwest of Lawrence. Water in the outcrop recharge area of influence is soft and low in minerals.

At the line of pressure contact a hydraulic trough and pressure barrier is developed. Within and along the southwestward side of this curtain the water is more highly mineralized and relatively hard having taken into solution a number of minerals from the sandstone in its down grade travel.

Construction of the Clinton reservoir will develop a new trough line as indicated on the map submitted herewith. Water in the Tonganoxie north and west of the reservoir should remain immobilized with little if any change. Down the Wakarusa valley to the eastward improvement should be expected. To the south and east beyond the static curtain mineralization will increase in wells to the south of the new curtain. North of this barrier the reverse should be true. Essentially there should be improvement or continuity in water quality except in a band centering on the line of pressure equalization.

INTRODUCTION

The purpose of this study is to formulate assumptions relating to the possible effect of the Clinton Reservoir on water supply and quality in the Tonganoxie sandstone aquifer in the Wakarusa drainage area downstream from the proposed lake site. This aquifer has been tapped for several decades to supply water for farm and to some degree for municipal usage. The principle municipal use is by the town of Overbrook in Osage County. This supply is obtained from wells in southwestern Douglas County. Some miscellaneous municipal usage was made of Tonganoxie water at Lawrence in the early development years. Other than as noted above the major utilization has been for farm water supply.

That portion of the aquifer of primary interest to this study occupies the western and north central sectors of Douglas County. The principle recharge area lies in southwestern Douglas and northwestern Franklin Counties. From this area hydraulic flow is to the north and northeast to the Wakarusa River valley. In this segment the aquifer is artesian, flowing down slope below relatively impervious shales. Down stream in Range 20 East the Wakarusa breaches the Tonganoxie sandstone. In this area the Tonganoxie in theory takes on the attributes of a water table aquifer. Probably this is the case only in part of the area. The cyclical range of precipitation in the area probably induces alternation in effluent and influent characteristics. Recorded water levels in the wells studied seem to indicate that the downstream recharge area creates an upslope pressure ridge which crests and then slopes downward and westward to meet the hydraulic gradient from the Ireland-Tonganoxie recharge area at points south of Lawrence. No current determination of the piezometric surface is possible from available data. The water levels quoted were not taken simultaneously. Seasonal and long range hydraulic factors can create considerable cyclical variance.

In general Tonganoxie water in the area is considered highly mineralized. The degree of mineralization is lowest at the two recharge areas and rises from both termini to a maximum in the area southwest of Lawrence. It also peaks under a band about four miles wide along the north edge pinch out of the old channel. This underlies most of Lawrence.

A comparison of water from alluvial wells supplying Lawrence with that from the Tonganoxie aquifer is included in the appendix.

When compared to the well water component of the Lawrence supply the water from both recharge areas is acceptable. Water from the outcrop area is lower in all catagories of mineral content. Chloride and fluoride contents of the Overbrook water are higher but both fall within the usual standards of acceptance. Tonganoxie wells in the peak area of mineralization have lower temporary hardness than those serving Lawrence. They are within acceptable standards for nitrates and bicarbonate but are much too high in fluoride, chloride and dissolved solids content. In its movement down slope the water continues to dissolve additional quantities of those minerals which are plentiful in the sandstone. Eventually this water reaches the pressure barrier at the water table trough and flow is reduced to minor cross barrier pulsations due to variable withdrawal from wells on either side. Probably this water continues to dissolve and assimilate more of the minerals. Since it is only brackish it is far below the saturation point.

As previously stated this study attempts to hypothesize the influence on the aquifer which will be interjected by construction of Clinton Reservoir.

STUDY PROCEDURE

Approach to this study has been concentrated almost exclusively to research of the literature involved. Field work has been limited to automobile tours of the study area. These have covered most of the locality accessible from roadways. Inspection of a few outcrops has helped to clarify the area stratification. Well inspection has been confined to observation of surface locations at a few key points. Tonganoxie outcrops were examined at Dightman's crossing and at the east boundary of Lawrence. Ireland outcrops were inspected in the vicinity of "Hole in the Rock" south of Lawrence.

Literature research involved all of the bibliographic material, but was centered largely on the reports by O'Connor, Sanders and Ball. Location and thickness data for the Lawrence and Stranger sandstones were obtained from Sander's report. O'Connor supplied well locations, well data and aquifer characteristics. From Ball came much insight into the classical hypotheses of Douglas sedimentation and stratification.Supplemental and confirmational data were gleaned from work of geologists listed.

ORIGIN AND STRUCTURE

This phase of the study will be covered only in generalized form since the classical stratigraphy has been detailed by more competent geologists. Pennsylvanian strata were laid down during alternating encroachment and retreat phases of the shallow inland seas of the period. Whether these phases were due to rising sea levels, rising or subsiding land or all three in combination is immeterial to the result. Within the megapattern of this period other rhythmic pulsations subdivided the column into divisional cyclothems. With reasonable consistency the deposition of cyclothems followed a repetetive pattern. From these patterns Moore (1936) outlined an ideal cyclothem of ten members. For varying reasons some cyclothems have been short changed and contain a lesser number of members but the basic pattern remains consistent. As initially designated the basal member is a sandstone which may rest disconformably on older members of varying age because of erosional activity prior to initial deposition of the new cyclothem. (Moore, 1936). These sandstones in general were channel fills. Moore considered them non marine. Deposition occured in previously eroded channels in a terrain which had approached base level. The composition is fine sand and silt brought down by sluggish streams and laid down and reworked in cross bedding through braided and meandering flow, much as is the case with depositional beds in valleys of modern streams such as the Kansas River.

The initial sandstone is followed by alternate shale and limestone layers to complete the cyclothem with the interjection in some cases of an underclay and coal contingent within or just above the sandstone. The Tonganoxie and Ireland sandstones are the basal members of two such cyclothems. In stratigraphic position the Ireland is in the upper cyclothem. In portions of the study area the two intervening limestones have been removed and at times the shales as well are missing or truncated.

The Tonganoxie sandstone was laid down in an eroded stream bed which enters the state from Missouri across the northeastern Kansas boundary and swings in a broad arc across Leavenworth and Douglas Counties and extends onward in a southwestern direction across Kansas into Oklahoma. Meanders of the ancient stream bed provided sites for the curves and lobes of the deposit. In a later stage the Ireland was produced in a similar manner. In position it lies above and athwart the Tonganoxie across southern Douglas and northern Franklin Counties. According to Moore the foreset beds of the Tonganoxie dip to the westward. This would seem to indicate a westward and southwestward trending stream and a detrial source to the eastward. Directional flow in the Ireland is not clear but an east to west trend seems reasonable.

CHARACTERISTICS

TONGANOXIE AND IRELAND SANDSTONES

The Tonganoxie and Ireland sandstones are of similar composition and texture. They grade from a silty composition to a relatively consistent sand content. Nearly all sand grains are fine. Nearly all deposition is cross bedded to a greater or lesser degree. Border portions of the sandstone carry a higher silt content with some shale. Porosity is adequate to admit a considerable volume of water but bedding characteristics are such that permeability is randomly directional. The coefficient of permeability ranges from 15 to 150 gpd per sq. ft. with well sorted beds ahowing a much higher coefficient locally (O'Connor 1960).

Tonganoxie well yields range from 5 to 50 gpm with increases to 150 gpm in local beds of higher permeability (O'Connor 1960). Mineral content is variable but relatively high in most categories, particularly chlorides. The fluoride content is high locally. Average thickness for the study area probably is 60-70 feet. The hydraulic gradient in the artesian sector is about 7 feet per mile. Mineralization increases down dip northwestward and down slope northeastward (O'Connor 1960).

MAPS

Map I is designed to show the physical characteristics of the study area. It covers all of Douglas County excepting a narrow belt of the westerly portion south of the Kansas River. Portions of bordering counties to the east, south and west are included. In addition to the areal surface the map delineates the subsurface thickness of the two sandstones which together provide storage and energy channels to activate the artesian aquifer under study. The map disregards correction line offsets on the boundary between T 15S and T 16S. This omission has little effect on the accuracy of portrayal since thickness contours of the sandstones are approximations even though they indicate the general depositional formations.

Isopach contours are from maps prepared by Sanders(1957). On the presentation map the thickness contours of the Ireland sandstone are shown in blue and of the Tonganoxie sandstone in red. Actually the thickness values indicated are composite values. In the one case all other sandstone in the Lawrence formation is included with the Ireland and in the second all other sandstone in the Stranger formation is included with the Tonganoxie. Sanders designates these as sandstones above and below the Haskell respectively. While they are undifferentiated on Sander's maps they are labeled Ireland and

Tonganoxie respectively on this map.

Outcrop limits of the Douglas group are shown on the map in purple. Areal location of the outcrop limits are also from Sanders (1957). Area outcrops of the Ireland and Tonganoxie are too limited in number for comparable delineation. The writer has visited only two outcrop locations for each sandstone. For the Ireland one is at "Hole in the Rock" in S 2 T 15S R 19 E. and one immediately north in S 35 T 14S R 19 E. The Tonganoxie outcrops are at Dightman's Crossing of the Wakarusa in S14 T 13S R 20 E and at the east boundary of Lawrence on 15th street, in S 5 T 13S R 20 E.

Thickness contours as shown by Sanders terminate at the Douglas outcrop limits. The two sandstones, of course, do underlie much of the outcrop area within their depositional limits. To minor degree the writer has attempted to extrapolate some of these contours using well log data as a basis. Results add little to the overall picture.

Well locations shown are from O'Connor (1960). Because of map scale limitation these have been designated in a random numerical order. Only those wells designated by O'Connor as tapping the Stranger or (? Stranger) formation have been included. Well numbers in question have been referenced in the appendix to O'Connor's numbering system. Data covering a few wells is questionable.

Location for Clinton reservoir is taken from U.S. Corps of Engineers maps. Locations for Lone Star Lake and Douglas County Lake are from county maps. Stream locations are incomplete but where shown are from a variety of sources.

Sections A B C and A' B C show down slope hydraulic gradients for two paths between the Overbrook and outcrop recharge areas. The well levels indicated were taken at times of well completion and range through a number of years. Simultaneous measurements if taken currently no doubt would show variance from these but the basic piezometric slope in all probability would be comparable. Section ADBC charts mineralization along a section practically coincident with section A' B C. Variance in well selection was dictated by availability of chemical data. This also is taken from O'Connor's report.

The boundary of surcharge effect from Clinton reservoir is indicated by an orange line. This outlines the trough which will form at the juncture of opposing hydrostatic pressures between the Lake and Overbrook recharge areas. While the location is hypothetical an actual static pressure curtain will appear somewhere near the indicated line.

A rough approximation of the existing line of equal pressure is indicated in brown. The area between the two lines should benefit in water quality.

Map II is a contour map showing the piezometric surface through the well field. This indicates the outcrop and southwestern recharge areas. A small recharge dome is indicated at the dam site area where Post Tonganoxie erosion has permitted the Wakarusa alluvium to rest directly on the Tonganoxie sandstone. In the Kansas River Valley the piezometric surface would seem to indicate some additional recharge although the Tonganoxie pinches out in the area.

On map III basal contours of the Tonganoxie are indicated. This indicates lows at the Overbrook recharge area and the hypothesized basin under Lawrence. Although it may not be continuous a higher ridge is indicated between them.

Map IV is a contour map of the upper surface at the Tonganoxie.

Map V is a contour map outlining the chloride content of a number of wells in the field. High chloride areas are indicated down slope from the Overbrook area and in the apparent basin under Lawrence.

Map VI locates a sectional route through wells between the Overbrook area and the northern portion of Lawrence. The corresponding cross section indicates the basal and upper Tonganoxie surfaces, the water level and relative salinity along the route cross sectioned.

DISCUSSION

With a conservation pool storage level of 875.5 feet the proposed Clinton Reservoir should alter the hydraulic characteristics of the Tonganoxie sandstone aquifer within the zone of influence of the reservoir. While the flood control area will range upward to 12,800 acres at a maximum elevation of 903.4 feet the effect of the incremental flood storage will be cyclical and temporary. The conservation pool area of 7,000 acres, however, will create a permanent hydraulic surcharge which will function as an artificial recharge area for the aquifer. Over an extended time period silting of the lake bed will retard infiltration to some degree but the extensiveness of the area should permit effective long range recharge.

The basic lake bed material will be Newman Terrace deposits in the Rock Creek, Deer Creek and Wakaruse River valleys and the valleys of minor tributaries. A small area of Buck Creek Terrace deposits will floor part of the lower reservoir below Clinton. On side slopes the contacts will be upper Lawrence shale deposits in the major pool area and some Oread limestone formation members on the upper reaches. Corps of Engineers boring logs at the dam site indicate the terrace deposits are in contact with the Tonganoxie. From about station 9 + 00 to station 65 + 00 in the southeastern segment of the structure bed rock line of the dam seat crosses the Lawrence shale, Haskell limestone and Vinland shale and runs through Tonganoxie sandstone a few feet below the stratigraphic position of the Haskell member. From station 12 + 00 to station 70 + 00 the United States Corps of Engineers borings do not log the Haskell limestone. Dip of the beds steepens at station 65 + 00. The local dip component along the longitudinal centerline of the dam is slightly more than a hundred feet per mile. From station 64 + 00 northwestward bed rock line crosses the Vinland shale and the Haskell limestone members and continues northwestward through the Lawrence shale.

Near the dam at the south side of the pool, percolating water must penetrate thirty five feet of alluvium and Lawrence formation, five feet of Haskell limestone where present, and sixteen feet of Vinland shale to reach the Tonganoxie aquifer. In the northern pool section the alluvium and Lawrence shale contingent increases up to 85 feet. For over a mile, however, the Tonganoxie lies directly beneath the valley alluvium. Since the regional dip is northwestward at 20 feet per mile and the Wakarusa slopes about 4½ feet per mile eastward the percolation depth increases to the westward about 25 feet per mile. Because the valley alluvium forms a water table aquifer in its own right and members above the Tonganoxie are missing in the area percolation resistance is limited and hydraulic interchange is possible.

If these assumptions are correct the reservoir should form a hydraulic dome applying artesian pressure to the Tonganoxie aquifer with the piezometric surface coning outward in all directions. A northwestward lobe of the aquifer extending down dip five miles to the north and some twenty miles to the west from the lake virtually would be isolated from other recharge areas. Water in this area probably is immobilized at present and highly mineralized. There are no record wells in this locality at present. This is a dead end area and should show no change unless heavily pumped in the future. Within the immediate lake area some wells will be drowned.

A few wells located between the Wakarusa and Rock Creek arms of the lake should show improvement in both softness and relative mineralization.

Southeast of the Lake area competetive pressurization will be in effect. The up slope area presently effecting recharge to the aquifer lies in southwestern Douglas, northwestern Franklin and eastern Osage Counties. The effective area of approximately one hundred square miles is due to superimposition of the Ireland sandstone above the Tonganoxie member. While the two sandstone members are separated by some seventy feet of shale and limestone they are in hydraulic contact through the sandy portions of the two shales and through fractures and joints in the Haskell limestone. In a portion of the area the Haskell member is missing. This appears to be the case in Township 15 South Range 18 East where driller's logs of the Overbrook wells show no limestone separating the Robbins and Vinland shales. It is possible also that pre-Ireland erosion may have eliminated separation of the two aquifers in some areas. In any case the Overbrook wells which are cased through the Ireland and produce from the Tonganoxie show static levels either in or above the Ireland. An isopach map prepared by Sanders (1957) indicates possible lobe separation of the Tonganoxie in Township sixteen south. However, a companion map shows the Ireland continuing southwestward and eastward for many miles. In much of the area the Ireland is near the surface and in fact outcrops in at least one locality at the junction of highways 56 and 59. The Ireland recharge area thus is quite extensive and hydraulic continuity to the Tonganoxie through intervening strata at the area of superimposition may be assumed.

Based on record water levels in existing wells the path of continuity of hydraulic pressure appears to bear northeast from the Overbrook well area to the Wakarusa Valley south of Lawrence. Thereafter the hydraulic level rises downstream to the Tonganoxie outcrop area in Range 20 East. Southeastward of this line the Ireland is superimposed above the Tonganoxie in some areas in which hydraulic interconnection would appear to be quite limited; otherwise water levels in wells in the valley southwest of Lawrence should be much higher that those recorded.

Assuming a percolation factor from the reservoir to the Tonganoxie aquifer comparable to that existing in southwest Douglas County, piezometric surface levels from the reservoir and from the Overbrook well recharge area should intersect along a line south and southeastward of the reservoir. Starting at the Tonganoxie zero thickness contour in T 14S near the county line it would curve around the Rock Creek reach of the lake. The hypothetical pressure contact line is assumed from water levels of existing wells. The line of coincidence should locate a hydraulic trough between the two areas of influence. From the Rock Creek reach the line should curve southeastward and then northeastward to terminate near the Tonganoxie sandstone outcrop in Range 20 East.

The existing pressure contact line should lie to the north of the hypothesized pressure curtain essentially paralleling it from the vicinity of the Tonganoxie outcrop to the west line of section 27 and then swing northwestward around the city.

There are two basic areas of high mineralization. The first lies up the hydraulic slope between the existing pressure curtain and the Overbrook recharge area. This will be affected to some degree by the reservoir. The second is a band stretching along the north bank pinch out of the old Tonganoxie channel from Lawrence to the lobe north of the reservoir. This appears to be a dead end sector in the aquifer.

It underlies most of Lawrence where most wells show high mineralization. Any alteration in these conditions due to reservoir influence seems highly doubtful unless the additional pressure from the reservoir tends to flush out the area in which case down valley wells may suffer a relapse in quality for a period of time.

Well data is limited but this area appears to have been subjected to deeper pre-Tonganoxie erosion than the reach along the Wakarusa Valley. The base of the Tonganoxie is
12-20-13
quite low. From the outcrop area at well Number 44 (12-20-30 cca) the base of the Tonganoxie on the average is above 750 feet along a line paralleling the Wakarusa and Rock Creek on the south. In the Lawrence basin the base of the Tonganoxie drops as low as 657 feet in well No. 4 (12-20-30 cca). Mineralization in this basin may be due in part to residual connate water or to stagnant concentration within the pool.

Basal Tonganoxie elevations in the Overbrook well area are also around 650 feet. Here however, heavy recharge and down slope flow appears to have swept the dissolved minerals down grade. Heaviest mineral content along the line of flow appears to be at the lip of the sub-Tonganoxie ridge. It would appear that the more concentrated solutions are partially dammed south of this ridge with less mineralized water flowing down slope above the crest.

It is also possible that mineral content of the sandstone in the two areas is heavier than elsewhere and that mineral content at specific wells is indigenous to those particular spots. However, the assumption of basin concentration seems more tenable.

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BIBLIOGRAPHY

Ball, Stanton M., 1964, Stratigraphy of the Douglas Group (Pennsylvanian, Virgilian) in the Northern Midcontinent Region: Thesis - University of Kansas, 490 pgs.

Bower, Richard R., 1961, Dispersal Centers of Sandstones in the Douglas Group (Pennsylvanian) of Kansas; Thesis - University of Kansas, p. 1-19

Dunbar, Carl O., 1962, Historical Geology; John Wiley & Sons, Inc., 2nd Edit., 4th Printing, 500 pgs.

Lins, Thomas W., 1950, Origin and Environment of the Tonganoxie Sandstone in Northeastern Kansas; Thesis - University of Kansas, 44pgs.

Merriam, Daniel F., 1963, The Geologic History of Kansas; State Geological Survey of Kansas, Bull. # 162, 317 pgs.

Moore, Raymond C., 1935, Stratigraphic Classification of the Pennsylvanian Rocks of Kansas; State Geological Survey of Kansas, Bull. # 22, 256 pgs.

O'Connor, Howard G., 1960 Geology and Ground Water Resources of Douglas County Kansas; University of Kansas Publication, State Geological Survey of Kansas, Bull. # 148, 200 pgs.

Sanders, Donald T., 1957, Sandstones of the Douglas and Pedee Groups as Possible Ground Water Reservoirs in Northeastern Kansas; Thesis - University of Kansas, 47 pgs.

APPENDIX

MINERAL CONTENT OF WATER

from

KANSAS RIVER ALLUVIUM VS. TONGANOXIE SANDSTONE

	Lawrence	Tong. Rech. Areas		Tonganoxie Peak area
	Alluvium	Overbrook	Outcrop	
Total diss. solids	567	565	396	4290
Ratio Ca+Mg/CL+K	5.6	0.3	2.1	0.05
Bicarbonate	444	346	399	520
Chloride	20	144	8	2200
Fluoride	0.3	0.7	0.2	2.5
Nitrate	1.8	0.4	0.3	5.6
Hardness (as carb.)	424	162	283	254

WATER WELLS IN THE STRANGER FORMATIÓN

DOUGLAS COUNTY

No.	Location No.	Surf. Elev.	Well Depth	Depth to Water	Tong Depth	Remarks
1	12-19-15 bc	840	210	-	-	salty aband
2	12-19-23 ab	890	131	73	-	salty
3	12-19-26abb	890	207	-	112-235	KGS test
4	12-20-30cca	845	222	-	164-188	salty 40 gpm
5	12-20-31 ba	860	160	-	125-160	salty
6	13-18-17 da	898	186	-	-	unused
7	13-18-23 ba	944	326	125	-	w. in 40' of ss
8	13-18-28 ab	-	340	155	-	salty @ 300'
9	13-18-28 ba	975	350	150	-	do
10	13-18-33 ad	850	150	-	-	1 gpm salty
*11	13-19-1 cc1	-	154	-	-	soda taste
12	13-19-1 cc2	885	118	-	112-118	salty aband
13	13-19-1 bc	998	300	-	248-300	KGS test
14	13-19-7 dd	846	146	35	-	-
15	13-19-10 dd	836	110	29	80-100	salty
16	13-19-11 dc	881	110	-	-	do
17	13-19-11da3	870	150	40	114-150	-
18	13-19-11 dd	850	101	55	80-101	water
19	13-19-12aab	882	163	70	115-165	good water
20	13-19-12aad	866	127	60	-	salty
21	13-19-12 cb	871	109	-	-	1 gpm
22	13-19-12cbb	873	124	60	105-124	much water
23	13-19-13 aa	830	70	20	-	salty
24	13-19-14 aa	852	111	32	80-111	10 gph
25	13-19-21 bb	861	99	48	60-90	observ w.
26	13-19-22 ad	886	169	85	93-166	50 gpm cl. 2400 ppm
27	13-19-23 da	856	140	-	85-136	10 gpm
28	13-19-24 aa	844	165	-	-	-
29	13-19-27 dd	1005	312	205	254-312	50 gpm
30	13-19-28cb2	865	107	20	-	-
31	13-19-36 ab	893	95	64	88-95	-
32	13-19-36 bb	893	118	-	75-115	some water
33	13-20-5 caa	890	160	88	-	-
34	13-20-5 dc1	921	185	109	135-185	-
35	13-20-5 dc2	916	174	110	157-174	5 gph
36	13-20-7 ad	812	143	74	95-143	-
37	13-20-8 ab2	912	184	104	100-184	some water
38	13-20-8 ad	880	160	40	105-160	1 gph
39	13-20-8 bb	-	130	-	-	-
40	13-20-6 aba	855	25	25	-	-

No.	Location No.	Surf. Elev.	Well Depth	Depth to Water	Tong Depth	Remarks
41	13-20-6 cd	872	19	19	-	-
*42	13-20-10ac	842	40	-	-	-
43	13-20-13ab	-	-	25	-	-
44	13-20-13cc	848	63	20	10-62	-
45	13-20-16aa	951	-	-	90-102	3/4 gph
46	13-20-16ab	-	147	80	-	250 gpd
47	13-20-16bb	833	90	50	-	2½ gpm
48	13-20-17aa	-	25	15	-	-
49	13-20-19cd	984	130	75	102-130	40 gpm
*50	13-20-21cc	818	50	20	-	-
51	13-20-22dc	900	148	82	100-148	-
52	13-20-23dc	898	108	-	73-108	-
53	13-20-25bb	894	117	-	77-110	some water
54	13-20-25cc	905	102	-	50-102	do
55	13-20-30ad	900	94	-	-	observ.well
56	13-20-30cd	898	132	60	112-132	some water
*57	13-20-31ad1	921	25	20	-	interm.
*58	13-20-31ad2	920	160	20	-	10 gph
59	13-20-32cc	-	127	-	-	salty
60	13-20-34dc	951	185	-	-	7½ gpm Chlor.
61	13-20-35cd	927	140	80	-	6 gpm
62	13-21-30aa2	-	60	-	-	1 gpm
63	13-21-30cc	-	-	42	-	some w.
64	14-17-24dd	1085	420	200	350-430	-
65	14-17-25ca	1090	458	-	320-458	K E R C Well
66	14-17-26ad	1084	405	186	354-398	20 gpm
67	14-17-35ad	1105	410	180	365-410	good water
68	14-18-6 ad	1101	300	150	-	bicarb. w.
69	14-18-8 ad	984	230	164	225-239	-
70	14-18-10bd	1078	325	125	305-325	-
71	14-18-11bb	1004	349	-	220-270	-
72	14-18-11db	915	160	70	135-153	2½ gpm
73	14-18-14aac	1028	368	181	240-358	K E R C 2300 chl.
74	14-18-18cb	1080	370	-	-	10 gpm bicarb.
75	14-18-23aa1	1040	377	-	327-335	100gpd
76	14-18-24aa	-	406	-	375-406	15 gpm salty
77	14-18-24cc	1042	335	-	-	salty
78	14-18-30ad	1112	489	250	428-475	10 gpm at 412'
79	14-18-35bb	1138	450	314	390-442	K E R C well
80	14-19-3 dd	-	121	96	-	some water
81	14-19-4 bb	900	142	-	120-142	14 gpm salty
82	14-19-9 cc	-	228	-	196-288	much water
83	14-19-15db1	1096	400	-	-	bicarb.
84	14-19-16bc	1070	304	234	200-204	much w. salty
85	14-19-19bb	-	356	-	234-356	some w.

No.	Location No.		Surf. Elev.	Well Depth	Depth to Water	Tong Depth	Remarks
86	14-19-19	cb	1100	300	-	-	salty
87	14-20-3	ac	-	114	50	-	$7\frac{1}{2}$ gpm
88	14-20-5	ac	-	148	-	-	little w.
89	14-20-5	da	-	30	5	-	-
*90	14-20-7	db	-	36	5	-	-
91	14-20-14	dc	-	37	17	-	-
92	14-20-21	bc	-	127	20	-	little w.
**93	15-17-1	aa	1138	327	-	-	12 gpm
94	15-17-1	ac1	1144	507	210	420-507	45 gpm
95	15-17-1	ac2	1141	497	210	395-495	45 gpm
96	15-17-13	dc	1080	315	-	220-315	K E R C well
**97	15-17-2	ab	1146	290	-	-	some w.
**98	15-18-1	aa	1095	301	20	-	do
99	15-18-7	aa	1035	434	-	347-401	K E R C $3\frac{1}{2}$ gpm salty
100	15-18-7	ad	1156	356	235	-	10 gpm salty
101	15-18-8	ba	-	403	-	-	4 gpm salty
*102	15-18-10	db	1054	348	86	-	18 gpm bicarb.
103	15-18-12	aa	1056	220	40	-	-
104	15-18-17	bb	1144	440	-	-	1 gpm

* Stranger Formation questionable

** Record indicates Lawrence Form. (depth corroborates)

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