STATE OF SOUTH DAKOTA
Ralph Herseth, Governor

STATE GEOLOGICAL SURVEY
Allen F. Agnew, State Geologist

SPECIAL REPORT 11

SHALLOW WATER SUPPLY FOR THE CITY OF FT. PIERRE

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INTRODUCTION

Present Investigation

This report contains the results of a special investigation by the South Dakota State Geological Survey during the summer of 1960 for the city of Ft. Pierre, Stanley County, South Dakota (fig. 1). The city now receives its water from three shallow wells in the northeastern part of town (fig. 2). These three wells have supplied an adequate amount of water to Ft. Pierre, but the quality of the water from City Wells No. 2 and 3 had been very poor. For this reason the State Geological Survey was asked to help the city find additional water supplies of a better quality.

A survey of the shallow ground water possibilities was made of an area in and around Ft. Pierre. This survey consisted of a review of the geology as mapped by the U. S. Geological Survey (Crandell, 1954), the drilling of 15 test holes, and the sinking of 7 shallow wells to collect water samples for analysis.

The field work and preparation of this report were performed by the writer under the supervision of Dr. Allen F. Agnew, State Geologist, and with the geologic assistance of Cleo Christensen, Lynn Hedges, and Richard Bruce. Special acknowledgment is made to the State Department of Health in Pierre, for the extremely rapid analysis of the water samples, which greatly assisted the writer in solving the problems. The help of the residents of Ft. Pierre is greatly appreciated, especially Mayor F. R. Fackelman, City Councilman Carl Fischer, and City Engineer Clyde Humphrey.

Location and Extent of Area

The city of Ft. Pierre is in Stanley County in central South Dakota, and has a population of 2649 (1960 census). The city is located at the juncture of the Missouri River and its tributary the Bad River,which are incised into the Missouri Plateau Section of the Great Plains Physiographic Province (fig. 1).

Climate

The climate is typically continental temperate, with large daily fluctuations in temperature. The average yearly temperature is 47.6° F and the average annual precipitation is 15.98 inches, at the U. S. Weather Bureau Station at the Pierre Airport.

Topography and Drainage

Most of the city of Ft. Pierre is located on the floodplain near the mouth of the Bad River; as a result, this part of the city is very flat-lying, having less than 20 feet of relief. The remainder of the town is on the steep shale bluffs of the rivers rising as much as 260 feet above the floodplain.

The area is well-drained to the southeast by the two rivers except for a slough in an ancient channel of the Missouri River, just north of the city (fig. 3).

FIGURE I
MAJOR PHYSIOGRAPHIC DIVISIONS OF EASTERN SOUTH DAKOTA

■ FT. PIERRE AREA

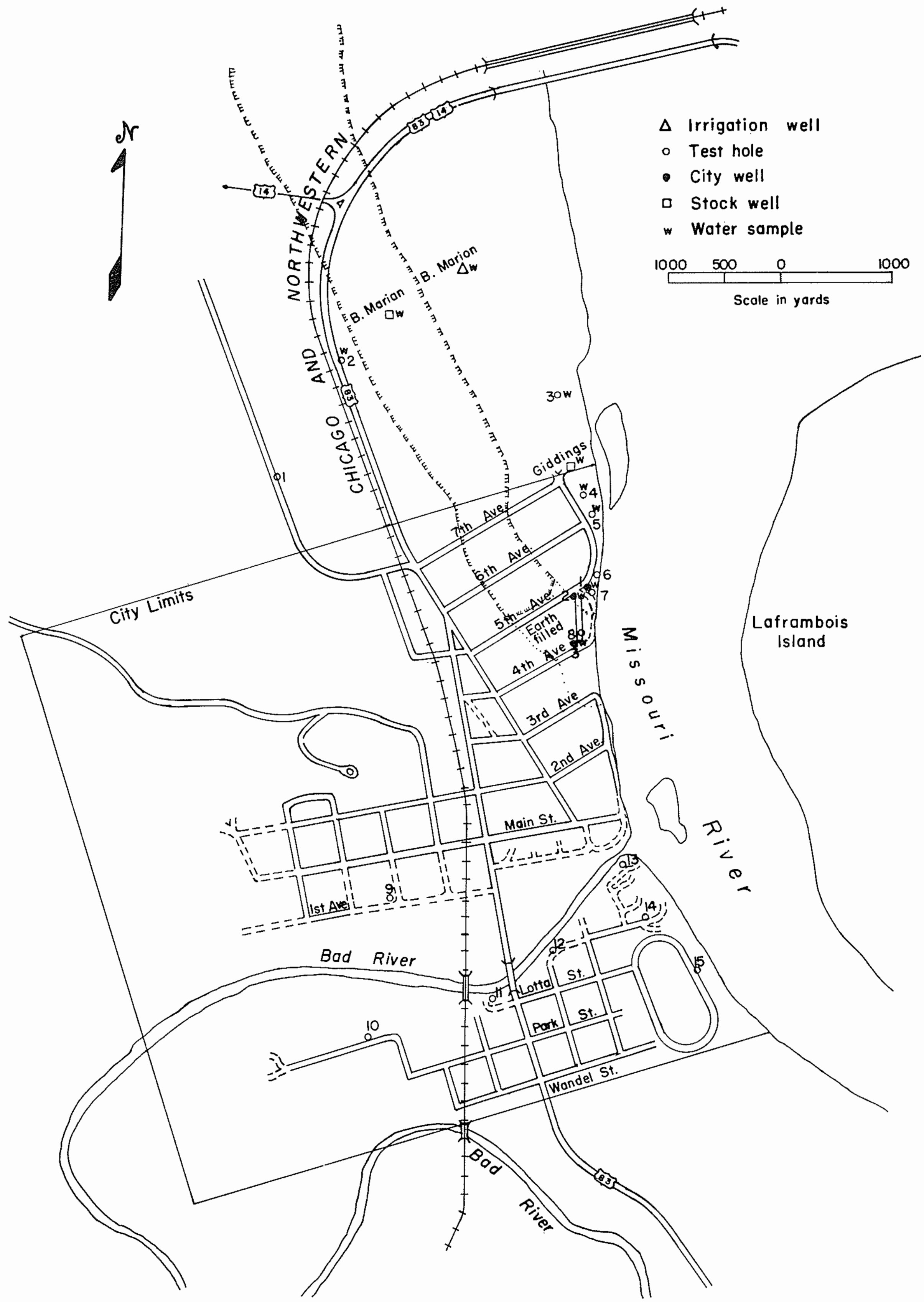

Figure 2
DATA MAP of FORT PIERRE and VICINITY
by
M. J. Tipton
August 1960

Drafted by Alan Lange

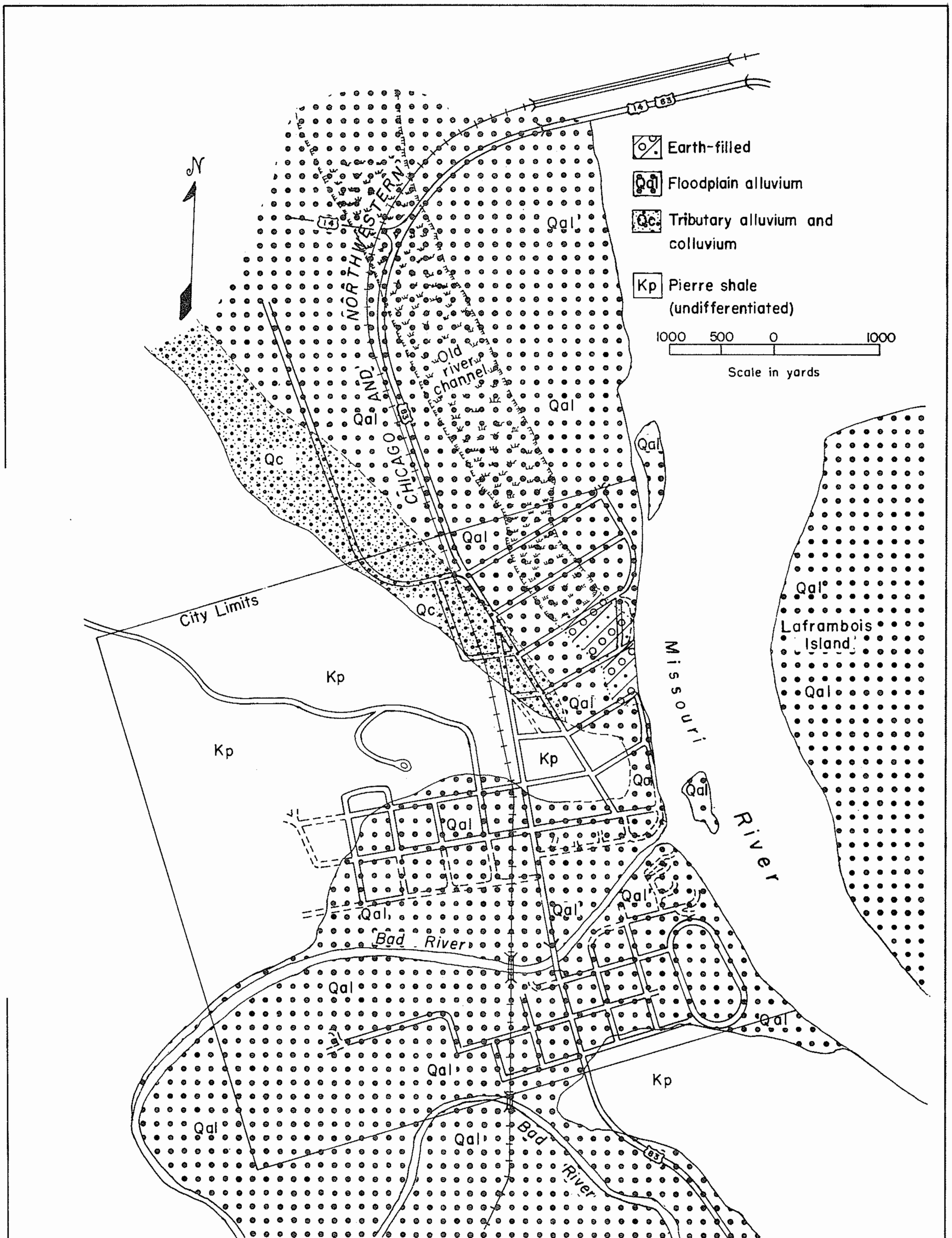

Figure 3
GEOLOGIC MAP of FORT PIERRE and VICINITY
by
M. J. Tipton
August 1960

Geology modified from
Crandell (1954)
Drafted by Alan Lange

GENERAL GEOLOGY

Surficial Deposits

The surficial deposits of the Ft. Pierre area are mostly the result of Recent stream deposition by the Missouri River and Bad River since the melting of the last ice sheet. These deposits consist of floodplain alluvium, terrace alluvium, and tributary alluvium and colluvium (Crandell, 1954).

The floodplain alluvium (Qal, fig. 3) consists of stream deposits of reworked glacial material, shale detritus, and sand and gravel of nonglacial sources. The deposits are predominantly silt- to pebble-size fragments, and range up to 51 feet in thickness.

The terrace alluvium of Crandell (1954), west of the old river channel, has not been differentiated from the floodplain deposits. Crandell stated that the terrace alluvium is made up of essentially the same material as the floodplain deposits, and can be distinguished from them because it occurs as terraces 8-20 feet above the floodplain. In the Ft. Pierre area this difference in elevation was not found, and therefore the deposits on both sides of the old river channel are mapped as floodplain alluvium (Qal).

The tributary alluvium and colluvium (Qc) consists of shale detritus and sand and gravel, which occurs as alluvial fans and slopewash in the area between the shale bluffs and the terrace alluvium. The total thickness of these deposits is not known.

Exposed Bedrock

Two members of the Pierre Formation of Cretaceous age are exposed along the bluffs of the Missouri River and Bad River (Crandell, 1954)--the Verendrye member which consists of olive-gray mudstone and siltstone, and the DeGrey member which consists of siliceous shale and claystone with bentonite beds. These two members are not differentiated on the geologic map (fig. 3) and will not be discussed further here, as they have no bearing on the shallow ground water prospects of the area.

OCCURRENCE OF GROUND WATER

Principles of Occurrence

Despite the common belief that ground water occurs in "veins" which criss-cross the country in a disconnected maze, it can be shown that water occurs almost everywhere in the ground, at depths below the surface which vary from a few feet to several tens of feet. The top of this zone of water saturation is known as the water table, and in the Ft. Pierre area it is generally at a depth of 10-30 feet except where the Pierre shale is at or near the surface; here the water table is usually much deeper.

Nearly all ground water is derived from precipitation. Rain or melting snow either percolates directly downward to the water table and becomes ground water, or drains off as surface water. Surface water either evaporates, escapes to the ocean by streams, or percolates downward to the ground water table. In general, ground water moves laterally down the hydraulic gradient, and is said to be in transient storage.

Recharge is the addition of water to an aquifer (water-bearing material), and is accomplished in three ways: (1) downward percolation of precipitation from the ground surface, (2) downward percolation from surface bodies of water, and (3) lateral underflow of water in transient storage.

Discharge, or the removal of ground water from an aquifer, is accomplished in four main ways: (1) by evaporation and transpiration by plants, (2) by seepage upward or laterally into surface bodies of water such as springs, (3) by lateral underflow of water in transient storage, and (4) by pumping.

The volume of water capable of being stored in a saturated material is equal to the volume of voids or pore spaces of the material. A measure of the capability of a material to store water is called porosity. Therefore porosity is the ratio of the volume of voids in the material to the volume of the rock. The shape and arrangement of grains in a material affects the porosity greatly, but size of the grains has no effect. Therefore a container filled with sand and a similar one filled with gravel, if the sand and gravel have the same shape and packing, could hold the same quantity of water. Sands and gravels usually have porosities that range from 20 to 40 percent. Sandstones normally have porosities of 15-25 percent; the lower porosity is due to closer packing and the effect of cementation.

The rate at which water will drain or pass through a material is a function of the permeability of the substance. Water will pass through a material with interconnected pores, but will not pass through a material with unconnected pores even if the latter material has a higher porosity. Therefore, permeability and porosity are not synonymous terms. As an example, clay has high porosity but will yield little water because it has low permeability.

The ratio of the volume of water that will drain from a material by gravity, to the volume of the material, is called specific yield. Values for specific yields vary from zero for plastic clays to nearly the total value of the porosity for coarse sands and gravels.

Thus, the type of deposit that contains the water governs the amount which can be withdrawn and, in part, how rapidly it can be recharged. For this reason, the object in trying to locate a good water supply is not to find a "vein" but rather, because water occurs almost everywhere, to find a sand or gravel deposit beneath the water table.

Ground Water in Alluvium

The alluvium present beneath the floodplains of the Missouri River and Bad River forms an excellent reservoir for ground water. These alluvial deposits are made up of silt- to gravel-size particles and are predominantly sand with some beds of gravel; the gravel is usually near the bottom of the deposit. The thickness of these alluvial deposits is as great as 51 feet (test hole 3, Appendix A), and averages about 40 feet.

Ground Water in Basal Gravels

The only glacial deposits in the Ft. Pierre area which appear to be potentially important in yielding ground water are the gravels near the bottom of the alluvium (test holes 4 and 5, Appendix A). It is believed that these gravels are possibly outwash materials that were deposited shortly after the Missouri River was formed. Whether these are outwash or alluvial gravels cannot be determined without extensive laboratory tests.

The thickness of these gravels is as much as 28 feet.

Ground Water in Bedrock

The bedrock exposed at the surface in the Ft. Pierre area is the Pierre shale, which is about 700 feet thick in this area. It is a very poor ground water reservoir because of its low permeability and the poor quality of the water.

Quality of Ground Water

Precipitated water is nearly pure before it reaches the ground. However, all ground water contains minerals which are obtained (1) from the atmosphere as the water vapor condenses and falls, (2) from soil and underlying deposits as the water percolates downward to the water table, and (3) from deposits below the water table, in which the water is circulating.

In general, it can be said the more minerals a water contains, the poorer its quality.

It was known that the water from City Well No. 1 had much better quality than that from either of the other two city wells (samples I, J, K, Table 1). In order to determine the cause, a series of wells were drilled. Each well was completed with 1¼-inch casing and a sandpoint. It was pumped with a pitcher pump until the water was clear of all sand and silt, and a water sample was taken. This sample was then analyzed by the State Department of Health in Pierre for total solids and hardness.

It was soon evident that there was a correlation between the quality of water and the location of the well with regard to the ancient river channel that extends northward from the city. Wells close to or west of the ancient river channel yield much poorer quality water than those to the east. Samples J, K, L, and M were taken from wells either close to or west of the old river channel, whereas samples B, C, D, E, F, G, H, and I were from wells east of the old channel. As can be seen, there is a striking difference in the chemical quality of the water in the two groups of samples (Table 1).

It is believed that the water in the alluvium beneath and west of the old river channel is being recharged from intermittent streams draining the Pierre shale bluffs to the west, and thus has acquired a considerable amount of minerals from the shale.This same area is also being recharged

Table 1.--Chemical Analyses of Water Samples in the Ft. Pierre Area*

(for location see Figure 2)

	Parts Per Million										Hard-ness	Total Solids
	Ca	Na	Mg	Cl	SO_4	Fe	Mn	N	F	pH	$CaCO_3$	
A	--	--	125**	250**	250**	0.3**	0.1**	10**	1.5**	--	--	500 to 1000 **
B	58	69	22	12	175	2.8	1.7	0.2	0.6	7.6	246	580
C	59	75	15	12	170	2.5	1.7	0.4	0.6	7.5	219	550
D	40	115	11	9	202	1.3	1.4	0.2	0.35	8.1	150	610
E	58	67	23	11	190	0.1	2.6	0.2	0.5	8.0	248	490
F	60	66	20	10	192	0.7	2.1	0.0	0.6	8.2	241	525
G	53	73	20	10	168	1.2	1.8	0.0	0.6	7.9	223	580
H	70	207	27	21	479	0.5	3.0	0.9	0.5	7.9	294	1013
I	76	140	27	20	337	0.6	2.2	0.0	0.7	7.3	307	758
J	91	267	37	32	615	0.7	2.4	0.0	0.6	7.6	388	1247
K	145	722	65	100	1548	2.0	2.8	2.5	0.7	7.5	637	2998
L	172	443	83	54	1313	2.1	4.8	0.0	0.7	7.9	787	2409
M	472	1771	250	223	4885	1.1	16	0.0	2.3	7.6	2242	8606
N	55	97	18	4	100	--	--	.06	--	8.0	237	477

A. U. S. Dept. of Public Health Drinking Water Standards (1960)
B. Survey test hole 4 (from 25 ft depth)
C. Survey test hole 4 (same depth as B; 24 hours later)
D. Survey test hole 4 (from 49 ft depth)
E. Giddings Farm well
F. Survey test hole 5
G. Survey test hole 3
H. B. Marion Irrigation well
I. City Well No. 1
J. City Well No. 2
K. City Well No. 3
L. B. Marion stock well
M. Survey test hole 2
N. Raw Missouri River water
* Samples analyzed by State Dept. of Health in Pierre, 1960
** not to exceed

from stagnant water in the old channel which percolates slowly downward into the alluvium below. The combination of the shale water and the stagnant channel water has produced a very poor quality water in this area of the alluvium. In fact, sample M (Table 1) shows one of the worst chemical quality analyses of any shallow water ever tested by the chemists of the State Board of Health.

The aquifer to the east of the old channel and thus that part nearest to the present Missouri River channel, is believed to be recharged almost wholly by the water from the river. This conclusion is supported by the similarity in the analysis of the water in this area and that of raw Missouri River water (sample N, Table 1).

This explanation can also account for the dissimilarity in the waters from the three city wells. This old river channel (fig. 2) formerly continued southward through the city of Ft. Pierre, but it has been filled in to its present position north of the city as Ft. Pierre grew. This fill does not prohibit the water from seeping into it from the unfilled part. City Well No. 1 is east of this filled-in channel, City Well No. 2 is on the edge of it, and City Well No. 3 is in the channel.

This explanation of recharge also shows why water from well No. 2 is not as poor in quality as that from well No. 3.

CONCLUSIONS AND RECOMMENDATIONS

It is recommended that the city of Ft. Pierre drill any new wells north and east of City Well No. 1. The best place is probably near the east end of Sixth or Seventh Avenues, in the vicinity of test holes 4 and 5 (fig. 2), and as close to the Missouri River as is practical. Another suggested location is just north of the above area, in the vicinity of test hole 3 (fig. 2).

It may be advisable not to bottom the wells in the shale beneath the sands and gravels, as some of the poor quality water could possibly seep upward into the wells.

It is suggested that the city contract with a commercial drilling company licensed in South Dakota to test-drill the areas recommended. The city officials should also consult the State Water Resources Commission with regard to obtaining a water right and a permit to drill a city well, and the State Department of Health with regard to the biological and chemical suitability of the water. A consulting engineering firm licensed in South Dakota should also be engaged to conduct pump tests and to design the water system.

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APPENDIX A

LOGS OF GEOLOGICAL SURVEY'S TEST HOLES IN THE FT. PIERRE AREA

(for locations, see Figure 2)

Test Hole No. 1
Surface Elevation: 1452 feet above sea level
Depth to water: none

0- 6	clay, medium-dark gray, dry, weathered
6-14	clay as above, but brown and unweathered

* * * * * *

Test Hole No. 2
Surface Elevation: 1431 feet
Depth to water: 16 feet

0- 4	brown clay to 2 feet, then dusty brown river silt
4- 9	alternate layers of hard brown clay and river silt; damp clay at 8 feet
9-14	same as above but 50 percent sand; very damp at 13 feet
14-19	60 percent sand containing much coal
19-34	sand, medium
34-37	sand, coarse
37-46	very fine sand and silt with about 30 percent clay
46-50	same only about 50 percent clay
50-62	same only about 30 percent clay
62	shale

* * * * * *

Test Hole No. 3
Surface Elevation:1431 feet
Depth to water: 15 feet

0- 4	sand, fine, tan
4- 9	silt-clay, buff to brown, dry
9-13	clay, dark gray-brown, damp
13-14	clay and fine sand, damp
14-15	silty sand, damp
15-33	sand, fine to silty
33-34	sand, fine to medium
34-38	sand, medium
38-51	sand, coarse
51-57	clay (?)
57-58	shale (?)

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Test Hole No. 4
Surface Elevation: 1428 feet
Depth to water: 12 feet

0- 8	sand, very fine, tan; moist at 4 feet
8-12	clay, brown
12-14	sand, fine
14-16	sand, fine, clayey
16-19	sand, fine
19-23	sand, fine
23-43	gravel, fine, well-sorted, clean
43-51	gravel, fine with a few pebbles
51-56	alternate hard layers
56-60	very hard drilling, Pierre shale (?) on bit

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Test Hole No. 5
Surface Elevation: 1427 feet
Depth to water: 12 feet

0- 4	sand, very fine, brown
4- 9	sand, fine, with brown clay at 6 feet
9-14	sand, fine, well-sorted, clean
14-24	sand, fine, with coal particles
24-29	sand, coarse, with some gravel
29-39	gravel, fine, well rounded

* * * * * *

Test Hole No. 6
Surface Elevation: not taken
Depth to water: 17 feet

0-12	sand, fine, brown, with some clay
12-17	clay, blue, putty-like
17-18	sand, very fine
18-26	sandpoint was driven in this interval, apparently same as above

* * * * * *

Test Hole No. 7
Surface Elevation: 1430 feet
Depth to water: 16 feet

0- 5	clay, sandy
5- 9	sand, fine, and clay
9-12	clay, black
12-14	sand, fine, well-sorted, with trace of clay
14-28	sand, fine; small pieces of coal and slightly coarser from 18-28

Test Hole No. 8
Surface Elevation: 1428 feet
Depth to water: 17 feet

0- 4	clay, brown, sandy, very dry
4- 9	sand, very fine, light tan, contains some clay
9-11	clay, sandy, brown
11-12	sand, medium
12-16	clay, blue-black
16-22	sand, gray to black, containing some coal
22-24	sand, brown
24-33	sand, gray, with some coal
33-37	sand, dark brown, with a trace of coal
37-41	sand, brown to light gray, fine to medium
41-43	sand, coarse
43-45	sand, fine
45-49	sand, coarse
49-53	augers shaking - may be clay or shale but probably gravel

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Test Hole No. 9
Surface Elevation: 1435 feet
Depth to water: none

0- 4	clay, hard, dry, brown
4- 9	clay, hard, brown to black
9-14	clay, light-brown, could not penetrate below 14 feet

* * * * * *

Test Hole No. 10
Surface Elevation: 1437 feet
Depth to water: 16 feet

0- 4	clay, brown
4- 9	clay, dark brown to black, dry
9-15	clay, brown, moist
15-24	clay, blue

* * * * * *

Test Hole No. 11
Surface Elevation: not taken
Depth to water: none

0- 4	clay, hard, brown, dry
4-14	clay, brown, damp, extremely hard drilling

* * * * * *

Test Hole No. 12
Surface Elevation: 1431 feet
Depth to water: 19 feet

0- 5	clay, hard, light brown, dry
5-19	clay, dark brown
19-29	clay, brown, containing 15-20 percent sand

* * * * * *

Test Hole No. 13
Surface Elevation: 1430 feet
Depth to water: 19 feet

0- 1	sand, well-sorted
1-29	clay, brown to dark brown, trace of sand 24-29

* * * * * *

Test Hole No. 14
Surface Elevation: 1429 feet
Depth to water: 17 feet

0- 1	sand, very fine
1- 7	clay, sandy, brown
7- 8	sand
8-19	clay, brown, sandy, soft
19-34	clay, brown, soupy, some sand
34-45	sand, fine to coarse, contains some coal
45	shale (?)

* * * * * *

Test Hole No. 15
Surface Elevation: 1430 feet
Depth to water: 11 feet

0- 9	clay, brown, 5 percent gravel 4-9
9-15	clay, brown, sandy
15-22	sand, very fine, with about 30 percent clay
22-44	sand, medium, clean, well-sorted
44	clay

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