WATER RESOURCES REPORT 16

GROUNDWATER RESOURCES OF NODAWAY COUNTY, MISSOURI

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MISSOURI GEOLOGICAL SURVEY AND WATER RESOURCES

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MISSOURI GEOLOGICAL SURVEY AND WATER RESOURCES ROLLA, MO.

William C. Hayes, State Geologist and Director

NODAWAY COUNTY, MISSOURI

COUNTY COVERED BY THIS REPORT

COUNTIES IN WHICH TEST DRILLING HAS BEEN COMPLETED

FIGURE 1

GROUNDWATER RESOURCES OF NODAWAY COUNTY

INTRODUCTION

This report has been prepared to aid in the location of groundwater supplies in Nodaway County. Nodaway County is one of several counties in northern and western Missouri experiencing difficulty in obtaining adequate amounts of usable ground water. This study is concerned with the location of areas within the county where ground water may be obtained for farm, irrigation, and municipal supplies. Emphasis is placed on ground water from the unconsolidated material above bedrock. Generally this water is of better quality than either surface or bedrock water. Systematic test drilling is the most reliable method of determining the areas in which this type of water occurs.

History of Program.-- The study is the continuation of a State sponsored groundwater program begun in 1955. Nodaway County is the seventeenth county to be studied during this program. Figure 1 shows those counties in which test drilling has been completed. Reports on these counties are available from the Missouri Geological Survey, P. O. Box 250, Rolla, Missouri.

Money used in the Nodaway County study was from the Survey's operational fund. However, six of the test holes which were drilled in 1957 were financed by an appropriation from the Missouri Postwar Surplus Reserve Fund. Drilling was contracted by bid.

The appended bibliography lists the previous work in the area of this report and in adjacent areas. Schweitzer (1892) gives a full discussion and description of the mineral springs and waters in Missouri. Hinds and

Greene (1915) and McQueen and Greene (1938) present excellent discussions of the bedrock geology in this and adjacent areas. Their reports contain well logs and discussions on the stratigraphy and structural geology of northwestern Missouri. Greene and Trowbridge (1935) discuss the preglacial drainage pattern of northwestern Missouri, and their pattern of the major channels is essentially correct. The present program has revealed many tributary channels and modifications of the major pattern. Flint (1957, p. 170) shows the regional drainage patterns during or preceding Pleistocene time. Kay and Apfel (1928) present a discussion of the Pleistocene deposits of Iowa which can also be applied to Missouri.

The report summarizes the results of an extensive test-drilling program and discusses in detail the water possibilities and the quality of the water from various sources in the county. The information which it presents was derived from: (1) the study of 143 test holes; (2) the extensive file of well logs maintained by the Missouri Geological Survey; and (3) the published and unpublished material related to or concerning water supply in Nodaway County.

Six test holes were drilled in Nodaway County during the period of June 26-28, 1957. Drilling resumed in the fall of 1958 and continued to the spring of 1959. A total of 143 test holes were drilled in the county. Geologists made a detailed log of each hole as it was drilled. The program was carried out under the supervision of W. B. Howe. Survey geologists assisting Heim and Martin in logging the test holes were Richard Gentile, J. R. McMillen, and Jack Wells.

Location and Size.-- Nodaway County (Figure 1) is located in the northwestern part of Missouri. It includes 877 square miles and is the fifth largest county in the state. The population in 1930 was 26,371; in 1940, 25,556; and in 1950, 24,033. This represents a decrease in population of 3.1% during the 1930-1940 period, and a decrease of 6.0% during the 1940-1950 period. In population, Nodaway County ranked twenty-fourth out of the 114 counties in the state in 1950.

Acknowledgments.-- Mr. W. B. Russell of Layne-Western Company, Kansas City, Missouri, provided information on several wells the company has drilled in Nodaway County. Mr. Russell was formerly employed by the Survey, and during that time he aided in the preliminary planning of the program in Nodaway County.

Mr. Carrol Lane and Mr. Clair Lane of the Lane Drilling Company, Blanchard, Iowa, were kind enough to supply the writers with copies of logs from numerous wells they have drilled in the county.

Mr. Frank C. Greene, formerly with the Missouri Geological Survey and now retired, discussed the groundwater problems of the county with the authors on numerous occasions. This assistance is gratefully acknowledged.

The writers also acknowledge the cooperation of Mr. Lloyd Brown, owner of the firm contracting the test-drilling work, and his employees, Mr. J. R. Lamme, driller, and Mr. G. Trump, assistant.

The writers also wish to thank the numerous State, County, and City officials for their cooperation. We wish to thank the Nodaway County residents for their cooperation and interest.

GROUNDWATER RESOURCES

Ground water in Nodaway County may be obtained from three sources:

(1) alluvium, (2) glacial deposits, and (3) bedrock. Test holes were located in such a manner as to supply the maximum amount of information for the first two of these units. Profiles of the major buried valleys were drawn in order to determine the thickness and extent of any water-bearing material. Survey geologists logged each hole as it was drilled, noting such information as type of material (sand, silt, or clay), size of sand grains, loose drilling zones, and depth to bedrock. Samples were collected at five-foot intervals and were placed on file at the Survey's office in Rolla.

The test holes were drilled with a rotary drilling rig. No casing was used, and samples were collected from the circulating water.

Table 1 summarizes the information from the 143 test holes. This information gives the amount of sand in each test hole and gives in gallons per minute (gpm) the driller's estimated water production which may be available in the vicinity of one or several test holes. Plate 2 shows the number and location of the test holes.

Ground Water from Alluvial Deposits

Alluvium is an unconsolidated material associated with present day rivers and streams. It consists of clay, silt, sand, pebbles, and boulders. The major alluvial deposits in Nodaway County are shown on Plate 1.

One Hundred and Two River Alluvium.-- Six test holes (Nos. 1050, 1051, 1104, 1123, 1144, and 1149) were drilled in the alluvium of One Hundred and Two River. In all the test holes except No. 1123, the alluvium overlies material of glacial origin. The alluvium ranges in thickness from approximately 27 to 115 feet. Its estimated production by the driller ranges from 2 to 500 gpm. In test holes Nos. 1050 and 1123, the total thickness of sand is alluvial material. Estimated production ranges from 2 to 5 gpm. The Missouri Geological Survey has information on two producing wells in One Hundred and Two River alluvium in Nodaway County. These wells produce from 17 to 25 gpm. See Table 3 for an average chemical analysis.

Nodaway River Alluvium.-- Four test holes (Nos. 1085, 1092, 1094, and 1131) were drilled in Nodaway River alluvium. The thickness of the alluvium ranges from 27 to 31 feet, and production estimates by the driller range from 0-20 gpm. The information which the Missouri Geological Survey has on three producing wells in Nodaway River alluvium in Nodaway County indicates that their production ranges from 10 to 100 gpm. See Table 3 for an average chemical analysis.

Platte River alluvium.-- Three test holes (Nos. 1058, 1068, and 1114) were drilled in Platte River alluvium. In each test hole, the alluvium was found to overlie glacial material. The alluvium ranges in thickness from 25 to 45 feet. In test hole No. 1114, all the sand encountered is associated with the alluvium, and the driller's estimated production is 3 to 5 gpm. The total estimated production from the alluvial material plus the glacial material in the other two test holes ranges from 50 to 150 gpm. The Missouri Geological Survey has information on one producing well in Platte River alluvium in Nodaway County. This well produces 40-45 gpm. See Table 3 for a chemical analysis.

Others.-- Alluvial deposits along other smaller rivers and streams in the county may produce small quantities of water, but the thickness and extent of the water-bearing material is quite variable.

Ground Water from Glacial Deposits

Most of Nodaway County is covered by clay, silt, sand, gravel, and boulders which were deposited during glacial time. When the glaciers entered Nodaway County, they deposited this material and covered the then existing topography. Old drainage patterns were buried, and present day drainage developed on this unconsolidated material. In most instances, the buried drainage patterns do not correspond to the present drainage. The channel fillings of sand and gravel are much the same as the alluvial deposits of the present river channels. By means of systematic test drilling, it is possible to locate and define the pre-existing drainage and to predict areas of potential water production.

Glacial deposits are very complex. Production from shallow sands (depths less than 50 feet) is variable and in dry seasons often ceases. The deeper water-bearing material is more dependable for continued production and constant quantity. Plate 1 shows the thickness of the unconsolidated material in Nodaway County.

A common misconception is that no water occurs below "blue clay". Of the 133 test holes which were drilled in glacial material, 15 encountered no aquifers in the glacial material, 20 encountered aquifers above the "blue clay", and 98 encountered water-bearing material below the "blue clay". Sixty-three tests which encountered sands and gravels below the "blue clay" penetrated 25 feet or more of the water-bearing material.

The complex system of buried valleys in Nodaway County is shown on Plate 2. A major east-west valley is located in the southern part of the county along the Nodaway-Andrew county line. This valley contains many test holes which penetrate several feet of excellent water-bearing material. See Fuller, et al., 1957.

The buried valley system underlying Maryville, Bedison, Conception Junction, and Clyde contains much water-bearing material with the most favorable material for the development of wells lying near the deeper parts of the channels in this system. However, there are records of poor producing wells located in the deepest parts of this buried valley system. Chemical analyses of water from wells in the glacial material are presented in Table 3.

Ground Water from Bedrock

No test holes were drilled into bedrock formations. Information on file at the Missouri Geological Survey indicates that water from bedrock (limestone or sandstone) is generally too highly mineralized to be suitable for most uses. The principal constituents which makes these waters unfit are the high sodium chloride (salt) and sulfate content. Chemical analyses of water from bedrock wells are listed in Table 3.

The Missouri Geological Survey has records of several wells that were drilled into bedrock in Nodaway County. The majority of these were drilled for oil exploration, but four were drilled for water. Three of these were dry, and the fourth produced 2 gpm. The possibilities of obtaining adequate quantities of usable water from the bedrock are very limited.

TABLE 1

SUMMARY OF TEST HOLE INFORMATION

Test Hole Number	Elevation (feet above mean sea level)	Depth to Bedrock (feet)	Total Amount of Sand (feet)	Driller's Production Estimate (gpm)*
972	952	85	15	2-3
973	1000	347	312	40-50
974	997	205	35	5-7
975	983	196	162	20-50
976	912	214	44	20-25
977	1009	196	12	2-5
1014	957	282	202	25
1015	970	218	25	10
1016	1035	139	2	2
1017	1070	211	122	75-100
1018	1059	238	152	10-20
1019	1083	214	94	25-35
1020	1067	231	141	15-20
1021	1055	224	174	10
1022	986	172	57	1
1023	950	114	3	0
1024	1040	68	6	1-2
1025	1060	81	4	1-2
1026	1059	113	13	1-2
1027	1064	106	0	0
1028	1052	151	110	25-30
1029	1060	253	113	25-30
1030	1017	48	5	1
1031	937	47	22	20-25
1032	988	87	24	15-20
1033	889	43	28	10-15
1034	958	102	10	1-2
1035	937	143	27	2-3
1036	1008	221	100	3-5
1037	881	22	0	0
1038	944	43	8	3-5
1039	1089	248	20	10-20
1040	1074	253	80	30-40
1041	1038	147	37	20-30
1042	1070	137	5	1
1043	1012	60	37	10-15
1044	1136	124	0	0
1045	1101	112	3	1-2

Test Hole Number	Elevation (feet above mean sea level)	Depth to Bedrock (feet)	Total Amount of Sand (feet)	Driller's Production Estimate (gpm)*
1046	1121	281	40	20-25
1047	1046	106	0	0
1048	1060	80	23	3-5
1049	1066	136	117	150-200
1050	1011	91	12	3-5
1051	959	186	85	200-300
1052	1073	277	56	50-60
1053	1080	103	73	25-30
1054	1083	129	17	5-10
1055	1107	200	5	2-3
1056	1045	263	33	6-8
1057	1086	299	100	10
1058	964	247	183	150
1059	1062	299	69	10
1060	930	127	42	10
1061	962	205	68	75-100
1062	948	195	10	10
1063	1053	324	130	50-60
1064	980	278	54	120-125
1065	1006	150	65	2-3
1066	1121	116	21	2
1067	1149	143	0	0
1068	1020	108	36	50-60
1069	1150	259	144	100-150
1070	1044	227	30	30-50
1071	1100	156	21	2-3
1072	1129	341	8	3-4
1073	1084	236	126	50-75
1074	1108	286	1	2-3
1075	1088	343	5	1-2
1076	1010	87	15	3-5
1077	1068	301	70	50-75
1078	1013	131	40	45-70
1079	1110	307	219	75-100
1080	1119	328	108	40-50
1081	1089	114	38	5-6
1082	1105	160	122	2-3
1083	1093	138	50	5-10
1084	1013	39	24	5-10
1085	905	27	12	10-15
1086	956	51	5	2-3
1087	927	48	13	3-5
1088	1038	82	7	2-3
1089	1039	82	0	0

Test Hole Number	Elevation (feet above mean sea level)	Depth to Bedrock (feet)	Total Amount of Sand (feet)	Driller's Production Estimate (gpm)*
1090	1131	192	105	20-25
1091	1074	92	3	0
1092	922	27	0	0
1093	1058	77	11	1-2
1094	943	31	12	2-3
1095	1037	73	30	2-3
1096	1134	221	73	2-3
1097	1080	261	15	2-3
1098	1068	188	63	2-3
1099	1146	227	64	10-15
1100	1184	233	128	2-3
1101	1110	161	31	10-15
1102	1109	99	0	0
1103	1022	117	68	25-30
1104	1007	141	60	10
1105	1020	87	77	20-25
1106	1138	Abandoned at 66 feet, igneous boulder		
1107	1143	60	0	0
1108	1165	110	75	10-15
1109	1162	202	77	5-10
1110	1164	152	50	10-15
1111	1109	88	7	1-2
1112	1116	96	57	5-10
1113	1086	89	54	25-30
1114	1055	73	6	3-5
1115	1144	141	6	1-2
1116	1141	116	28	4-6
1117	1075	39	14	5-10
1118	1167	127	18	3-5
1119	1212	155	90	3-5
1120	1204	167	65	20-25
1121	1173	156	117	3-7
1122	1158	163	50	5-10
1123	1020	41	33	2-5
1124	1120	135	34	1-2
1125	1150	226	91	5-10
1126	1140	285	132	5-10
1127	1189	294	37	2-3
1128	1140	246	130	3-5
1129	1073	147	21	1-3
1130	1055	151	3	0-2
1131	932	30	17	20
1132	1112	137	21	2-3
1133	1030	39	0	0

Test Hole Number	Elevation (feet above mean sea level)	Depth to Bedrock (feet)	Total Amount of Sand (feet)	Driller's Production Estimate (gpm)*
1134	958	40	9	15
1135	1145	307	100	10
1136	1081	119	45	5
1137	1145	207	59	10
1138	1158	268	73	5-10
1139	1089	131	32	5-10
1140	1197	193	10	0-1
1141	1146	131	14	5-10
1142	1200	186	11	1
1143	1189	Abandoned at 90 feet, equipment trouble		
1144	998	161	123	50-75
1145	1108	196	63	3-5
1146	1120	90	8	0
1147	1167	209	57	15-20
1148	1203	349	30	1-2
1149	967	203	186	500
1150	974	338	98	5-10
1185	1146	238	7	1-2

*The driller's estimate is based on the character of the sand and gravel, the way in which it drills (loose or tight), and knowledge of what wells in similar materials have produced.

WATER QUALITY

Water quality is commonly considered from two aspects, bacteriological and chemical. The importance and various limits of these aspects depend upon the use to which the water is to be put. The following discussion deals primarily with water to be used for domestic purposes.

Bacteriological.-- The amount and type of bacteria in water is most important in determining its purity for drinking. Surface water supplies and groundwater supplies that may possibly be contaminated require periodical checking along with constant treatment with purifying agents to insure their safety. Bacteriological analysis reveals the presence of bacteria that may cause typhoid, dysentery, and other such diseases. Any surface supply should be considered contaminated and treated as such. Most groundwater supplies for public use in northwestern Missouri are treated as though contaminated, by order of the Division of Health, Jefferson City, Missouri.

In a properly constructed drilled well, there is not much danger of contamination. Proper construction includes adequate provisions for the exclusion of surface water and sterilization of the well upon its completion by the driller. Arrangements for a bacteriological analysis can be made through the district offices of the Division of Health and, in some cases, through the water department of the nearest town having a public water supply.

Chemical.-- The physical and chemical properties of water are very important in determining the type of treatment necessary to make the water usable. Table 2 lists some of the chemical characteristics of acceptable water. Chemical analyses are made by the Division of Health and by the Missouri Geological Survey, Box 250, Rolla, Missouri.

TABLE 2

CHEMICAL CHARACTERISTICS OF WATER FOR DOMESTIC USE

Constituents	Maximum Allowable Amounts in Parts Per Million	Effect of Excess
Chloride	250.0	Salty taste
Fluoride	1.5	Mottling of teeth
Iron	0.3	Staining
Nitrate	45.0	Danger to infants
Sulfate	250.0	Permanent hardness

Other information given in a chemical analysis includes remarks about turbidity, odor, hardness, etc. This information can be used to determine the suitability of the water for household use, irrigation, or stock; whether incrustation or corrosion of metals might occur; and also to indicate the type of treatment, such as softening or iron removal, that might be beneficial.

In general, the water from alluvial and glacial deposits is hard and contains an excess of iron, and in many cases may require treatment. Bedrock water is more variable, but it is generally too high in chloride and sulfate to be usable.

CITY WATER SUPPLIES

The production given for cities having a municipal supply is based on the capacity of the existing water treatment plants and does not indicate the maximum potential yield of the aquifer.

Barnard.-- No municipal water supply. Most likely area for future development, One Hundred and Two River alluvium.

Burlington Junction.-- Municipal water supply. City has one well located in Nodaway River alluvium. The well is 38 feet deep and pumps approximately 10 gpm. Water is filtered and chlorinated.

Clearmont.-- No municipal water supply. Most likely area for future development, Nodaway River alluvium. See test hole No. 1131.

Clyde.-- No municipal water supply. Most likely area for future development, glacial material in buried channel. See test hole No. 1063.

Conception.-- No municipal water supply. Most likely area for future development: Platte River alluvium; surface resevoir; or glacial material in buried channel. Yield from the buried channel in the immediate vicinity of Conception is variable.

Conception Junction.-- Municipal water supply in operation since May 1958. City has one well located in Platte River alluvium. Well produces 40-45 gpm. Water treatment consists of filtration and addition of alum, chlorine, and lime.

Elmo.-- No municipal water supply. Most likely area for future development, Mill Creek alluvium. See test hole No. 1134.

Graham.-- No municipal water supply. Most likely area for future development, Elkhorn Creek alluvium or Nodaway River alluvium. See test hole No. 1033.

Guilford.-- No municipal water supply. Most likely area for future development, Platte River alluvium.

Hopkins.-- Municipal water supply. City has two pumps: Pump No. 1

has a capacity of 25 gpm, Pump No. 2 has a capacity of 17 gpm. Pump No. 1 produces from 2 wells approximately 23 feet deep. Pump No. 2 produces from 6 sand points approximately 23 feet deep. All wells are located in One Hundred and Two River alluvium. Water is treated with chlorine and soda ash.

Maryville.-- Municipal water supply from surface reservoir. Water obtained from the One Hundred and Two River. Water treatment consists of filtration and addition of alum, chlorine, and lime.

Parnell.-- No municipal water supply. Most likely area for development, Platte River alluvium. See test hole Nos. 1113 and 1114.

Pickering.-- No municipal water supply. Most likely area for future development, One Hundred and Two River alluvium.

Quitman.-- No municipal water supply. Most likely area for future development, Nodaway River alluvium. See test hole No. 1085.

Ravenwood.-- No municipal water supply. Most likely area for future development, Platte River alluvium. See test hole No. 1068.

Skidmore.-- Municipal water supply. City has two wells located in Nodaway River alluvium. The wells are approximately 35 feet deep. The south well produces 100 gpm and the north well produces 85 gpm. Water is chlorinated.

EXPLANATION OF PLATES

The information shown on the Thickness Map and the Bedrock Contour Map is accurate only to the degree of presently known data. As more information becomes available these maps will be modified. The Thickness Map, based on the Bedrock Contour Map, is very generalized.

Plate 1, Thickness of Unconsolidated Material Map.-- This map shows the thickness of the unconsolidated material overlying the bedrock. In general, it can be said that the thicker the unconsolidated material, the greater the possibility of encountering water-bearing material. This map may be used to estimate the amount of potential water-bearing material available and the approximate depth of a well at a given point.

Plate 2, Bedrock Contour Map.-- This map, by means of contour lines, shows the configuration of the bedrock surface based on interpretation from test hole data and bedrock exposures. This is the way the land surface would probably appear if all the unconsolidated material were removed. Contour lines are imaginary lines connecting points of equal elevation.

SUMMARY

Wells in the alluvium of the major streams of Nodaway County (One Hundred and Two River, Nodaway River, and Platte River) will produce sufficient water for domestic needs and, at places, sufficient water for municipal supplies and irrigation. This water normally needs treatment for removal of iron and hardness.

The occurrence of water in glacial deposits is more variable than water from alluvial deposits. Shallow wells, less that 50 feet in depth, commonly experience seasonal variations in water level. In periods of prolonged drought, these wells very often "go dry". The deeper wells are more likely to be consistent and will produce larger quantities of water than the shallow wells.

The buried river valleys are areas of potentially high-yield wells. However, because there are on record some wells of the low-yield within these valleys, it is recommended that all the information available for such an area be obtained before any test is drilled.

Water from the glacial deposits may need treatment for removal of iron and hardness.

The possibility of obtaining usable water from bedrock is very remote. In all known cases in Nodaway County, bedrock water is too highly mineralized to be fit for human consumption.

For further information write: Missouri Geological Survey and Water Resources, Post Office Box 250, Rolla, Missouri 65401.

TABLE 3

CHEMICAL ANALYSES OF WATER FROM VARIOUS SOURCES

One Hundred and Two River Alluvium

Source: Hopkins municipal supply

Constituents	Minimum	Maximum	Average	Number of Analyses
	Parts Per Million			
Turbidity	0.6	25.0	9.85	11
pH	6.5	7.25	6.73	8
Alkalinity ($CaCO_3$)	163.0	272.0	197.07	11
Bicarbonate (HCO_3)	191.9	331.4	224.51	11
Silica (SiO_2)	8.0	16.0	12.28	8
Oxides (Al_2O_3, Fe_2O_3, TiO_2, etc.)	0.3	1.6	0.11	4
Calcium (Ca)	17.1	185.6	128.82	11
Magnesium (Mg)	4.1	39.2	23.80	11
Sodium (Na) and Potassium (K) as Na	14.2	418.9	94.53	11
Total Iron (Fe)	0.04	3.0	0.42	11
Sulfate (SO_4)	106.8	228.2	191.09	11
Chloride (Cl)	32.7	367.8	157.69	11
Nitrate (NO_3)	0.20	17.4	2.37	10
Total Dissolved Solids	441.0	1266.0	935.27	11
Total Hardness	60.0	556.0	419.73	11
Carbonate Hardness	60.0	213.0	177.77	11
Noncarbonate Hardness	5.0	424.0	266.16	10

Nodaway River Alluvium

Source: Burlington Junction municipal supply

Constituents	Minimum	Maximum	Average	Number of Analyses
		Parts Per Million		
Turbidity	0.1	50.0	20.44	10
pH	6.8	7.0	6.90	5
Alkalinity ($CaCO_3$)	186.0	221.0	203.81	12
Bicarbonate (HCO_3)	227.0	269.7	248.40	12
Silica (SiO_2)	18.4	24.0	22.13	5
Oxides (Al_2O_3, Fe_2O_3, TiO_2, etc.)	1.0	2.0	1.62	7
Calcium (Ca)	49.6	59.2	54.55	12
Magnesium (Mg)	14.4	16.2	15.12	12
Sodium (Na) and Potassium (K) as Na	20.9	35.7	24.42	12
Total Iron (Fe)	0.04	15.0	4.91	12
Sulfate (SO_4)	11.3	41.8	27.08	12
Chloride (Cl)	13.2	18.8	16.15	12
Nitrate (NO_3)	0.03	0.85	0.27	12
Total Suspended Matter	11.0	18.8	14.00	4
Total Dissolved Solids	296.0	435.0	340.16	12
Total Hardness	183.0	208.6	198.36	12
Carbonate Hardness	183.0	207.0	192.77	12
Noncarbonate Hardness	9.0	22.0	16.77	4

Nodaway River Alluvium

Source: Skidmore municipal supply

Constituents	Minimum	Maximum	Average	Number of Analyses
	Parts Per Million			
Turbidity	0.1	100.0	25.39	18
pH	6.4	7.2	6.76	12
Alkalinity ($CaCO_3$)	79.0	190.0	137.92	18
Bicarbonate (HCO_3)	96.6	257.8	157.36	18
Silica (SiO_2)	12.0	28.0	19.75	12
Calcium (Ca)	56.3	97.9	71.37	18
Magnesium (Mg)	9.4	35.0	15.50	17
Sodium (Na) and Potassium (K) as Na	17.0	34.9	23.53	18
Total Iron (Fe)	0.2	15.0	3.29	18
Sulfate (SO_4)	35.8	124.3	69.26	18
Chloride (Cl)	13.4	54.5	32.95	18
Nitrate (NO_3)	0.05	0.32	0.208	6
Total Dissolved Solids	342.0	578.0	413.57	18
Total Hardness	186.0	288.0	238.13	18
Carbonate Hardness	79.0	190.0	137.25	18
Noncarbonate Hardness	47.0	192.0	100.88	18

Platte River Alluvium

Source: Conception Junction municipal supply - one analysis

Constituents	Parts Per Million
Turbidity	15.0
Odor	none
pH	6.8
Alkalinity ($CaCO_3$)	168.5
Phenolpthalein	0.0
Methyl Orange	168.5
Carbonate (CO_3)	0.0
Bicarbonate (HCO_3)	205.6
Silica (SiO_2)	7.0
Oxides (Al_2O_3, Fe_2O_3, TiO_2, etc.)	0.7
Calcium (Ca)	166.5
Magnesium (Mg)	42.7
Sodium (Na) and Potassium (K) as Na	56.6
Total Manganese (Mn)	2.97
Total Iron (Fe)	4.40
Dissolved Iron	0.17
Precipitated Iron	4.23
Sulfate (SO_4)	370.4
Chloride (Cl)	69.5
Nitrate (NO_3)	31.6
Fluoride (F)	0.3
Total Suspended Matter	12.0
Total Dissolved Solids	918.0
Total Hardness	591.5
Carbonate Hardness	168.5
Noncarbonate Hardness	423.0

Glacial Deposits

Source: A - Benedictine Convent, Clyde

B - Conception Abbey, Conception

C - Grey's Skelly Service Station, SE¼ SW¼ SE¼ sec. 31, T. 65 N., R. 35 W.

Constituents	A	B Parts Per Million	C
Turbidity	2.0	N.D.	0.0
pH	7.7	N.D.	7.1
Alkalinity ($CaCO_3$)	467.0	244.0	280.0
Phenolpthalein	10.0	N.D.	0.0
Methyl Orange	457.0	N.D.	280.0
Carbonate (CO_3)	6.0	8.4	0.0
Bicarbonate (HCO_3)	557.5	297.6	341.6
Silica (SiO_2)	6.0	16.8	23.7
Oxides (Al_2O_3, Fe_2O_3, TiO_2, etc.)	1.3	N.D.	0.3
Calcium (Ca)	68.5	88.3	269.9
Magnesium (Mg)	22.1	17.9	80.5
Sodium (Na) and Potassium (K) as Na	449.3	46.9	136.5
Total Manganese (Mn)	0.12	N.D.	0.53
Total Iron (Fe)	1.68	0.25	0.13
Dissolved Iron	0.63	N.D.	0.04
Precipitated Iron	1.05	5.98	0.09
Sulfate (SO_4)	462.2	76.3	926.8
Chloride (Cl)	205.0	22.9	15.3
Nitrate (NO_3)	0.6	8.51	4.6
Fluoride (F)	0.6	N.D.	0.8
Total Suspended Matter	0.0	312.0	0.0
Total Dissolved Solids	1517.0	474.0	1779.0
Total Hardness	262.0	294.1	1005.3
Carbonate Hardness	262.0	244.0	280.0
Noncarbonate Hardness	0.0	0.0	725.3

Bedrock

Source: A and B - Owner: Elmo School Board
A - Top of water at 160 feet (Shawnee Group)
B - Bottom of water at 486 feet (Douglas Group)

C - Owner: H. L. Leeper
Location: SW¼ SE¼ sec. 3, T. 62 N., R. 37 W.
Depth of sample: Unknown
Total depth of well: 374 feet (Pennsylvanian)

D - Owner: J. E. Palensky, et al.
Location: Wallace No. 1, SW¼ NW¼ NW¼ sec. 10, T. 65 N., R. 36 E.
Depth of sample: 1942 feet (Warsaw) and 2030 feet (Burlington-Keokuk) (combined)

Constituents	A	B	C	D
	Parts Per Million			
Alkalinity ($CaCO_3$)	388.5	541.9	N.D.	792.0
Carbonate (CO_3)	0.0	0.0	26.5	299.9
Bicarbonate (HCO_3)	473.8	660.8	0.0	492.1
Silica (SiO_2)	2.8	7.2	7.2	30.0
Oxides (Al_2O_3, Fe_2O_3, TiO_2, etc.)	0.80	2.40	2.3	2.0
Calcium (Ca)	127.9	95.9	103.1	7.1
Magnesium (Mg)	45.4	37.3	75.1	9.6
Sodium (Na) and Potassium (K) as Na	1204.6	1610.0	3576.1	1177.8
Sulfate (SO_4)	894.0	865.4	531.9	693.0
Chloride (Cl)	1412.8	1729.3	6469.6	699.0
Total Dissolved Solids	4182.4	4854.0	12081.2	2840.0
Total Hardness	505.9	392.7	N.D.	63.1
Carbonate Hardness	388.5	392.7	N.D.	63.1

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GEOLOGIC TIME SCALE, TYPES, AND USES OF MISSOURI ROCKS

MAJOR DIVISIONS		TYPE AND DISTRIBUTION OF ROCK	ECONOMIC UTILIZATION
ERAS	PERIODS		
CENOZOIC	QUATERNARY 0 1,000,000 Q	*Glacial deposits; loess; silt, sand, and gravel in modern streams and rivers.*	*Parent material of much of state's soil; important source of water; chief source of sand and gravel.*
CENOZOIC	TERTIARY 1 69,000,000 T	*Sand, gravel, clay, and shale; largely restricted to Lowland region of southeastern Missouri.*	*Water, ceramic clay, bleaching clay.*
MESOZOIC	CRETACEOUS 70 65,000,000 K	*Clay and sand; restricted to southeastern Missouri as above.*	*Water, ceramic clay, sand.*
MESOZOIC	JURASSIC 135 45,000,000 J	*No rocks of Jurassic age in state.*	
MESOZOIC	TRIASSIC 180 40,000,000 R̄	*No rocks of Triassic age in state.*	
PALEOZOIC	PERMIAN 220 55,000,000 P	*Sandstone; known from single locality in Atchison County.*	*No economic utilization.*
PALEOZOIC	PENNSYLVANIAN 275 55,000,000 IP	*Shale, limestone, sandstone, clay, and coal; present in more than two-thirds of the counties of the state; extensive in western and northern Missouri.*	*Coal, ceramic materials (including fireclay); limestone and shale for cement manufacture; oil, gas, and water; an important source of limestone in many western and northern counties; asphaltic sandstone, and iron.*
PALEOZOIC	MISSISSIPPIAN 330 25,000,000 M	*Predominantly limestone, some shale; principal areas of outcrop are southwestern, central, east-central, and northeastern parts of the state.*	*Lime, limestone, marble (Carthage), raw material for cement, water, tripoli, lead, zinc, and iron.*
PALEOZOIC	DEVONIAN 355 55,000,000 D	*Predominantly limestone; exposed in central, eastern, and southeastern Missouri.*	*Limestone, marble (Ste. Genevieve Co.).*
PALEOZOIC	SILURIAN 410 20,000,000 S	*Predominantly limestone; exposed in northeastern and southeastern Missouri.*	*Limestone and dolomite.*
PALEOZOIC	ORDOVICIAN 430 60,000,000 O	*Dolomite (magnesian limestone), limestone, sandstone, and shale; extensively exposed in Ozark area as far north as Montgomery County and west to McDonald and St. Clair counties; also exposed in parts of Ralls, Pike, and Lincoln counties.*	*Sand for glass and ground silica, limestone, dolomite, water, oil (St. Louis County), building stone, raw material for cement, iron, and terrazzo chips.*
PALEOZOIC	CAMBRIAN 490 50,000,000 €	*Dolomite, sandstone, and shale; major outcrops restricted to St. Francois Mountain area.*	*Lead, zinc, silver, cobalt, nickel, copper, barite, iron, water, dolomite, terrazzo chips, and building stone.*
PRECAMBRIAN 540 *Includes several divisions of Era rank. Total time involved may have been as much as four billion years.*		*Igneous and metamorphic rocks; igneous exposed in St. Francois Mountain area.*	*Iron, granite for building and monumental stone.*

NOTE: Age data based on latest published results of isotopic measurements.
Chart not drawn to scale; 0 - 540: cumulative age in millions of years.

JANUARY 1960 MISSOURI GEOLOGICAL SURVEY AND WATER RESOURCES

The Geologic Time Scale

The Geologic Time Scale covers that interval of time from the formation of the first rocks in the earth's crust to the present. The length of this interval of time has been determined from a study of the rocks exposed at the surface of the earth and those recovered from well borings. It covers an interval of many millions of years. Throughout this time, rocks have been formed by the various geologic processes in the same manner as they are today. At present, a great deal of rock-forming material is being deposited at the mouths of large rivers as accumulations of sand and clay. As in past geologic ages, this material will eventually form the sandstone and shale beds so familiar to many of us.

Since the rock-forming processes have been continuous, rock formations are of various ages. In Missouri, the oldest rocks are the granite and related rocks of Precambrian age and are exposed at the surface in the St. Francois Mountains of southeastern Missouri. Radiometric age determinations indicate that they were formed one and a quarter to one and a half billion years age. All other rock units in the state were deposited after the Precambrian rocks, but long before the deposits of clay, sand, and gravel in our modern streams and rivers.

In order to date the time during which various rocks were formed, geologists have divided the long expanse of time covered by the geologic time scale into time units called eras and periods. Thus, as the historian divides time into years, months, and days, the geologist divides geologic time into eras, periods, and smaller divisions.

The major divisions of the geologic time scale and the type, distribution, and economic utilization of rocks in Missouri are listed on the reverse side of this sheet. For example, the Mesozoic era is estimated to have laster 150 million years. It has been subdivided into the Triassic, Jurassic, and Cretaceous periods. Geologists have determined that these periods lasted 40, 45, and 65 million years, respectively. Although rocks of Triassic and Jurassic age have not been found in the state, rocks of Cretaceous age do occur in the lowland region of southeastern Missouri. They are principally clays, sands, and limestones which were deposited in a shallow sea over 70 million years ago. The major economic products derived from them are water, ceramic clay, and sand.

PLATE I

MAP OF NODAWAY COUNTY SHOWING THE THICKNESS OF UNCONSOLIDATED MATERIAL

BY

G. E. HEIM

J. A. MARTIN

W. B. HOWE

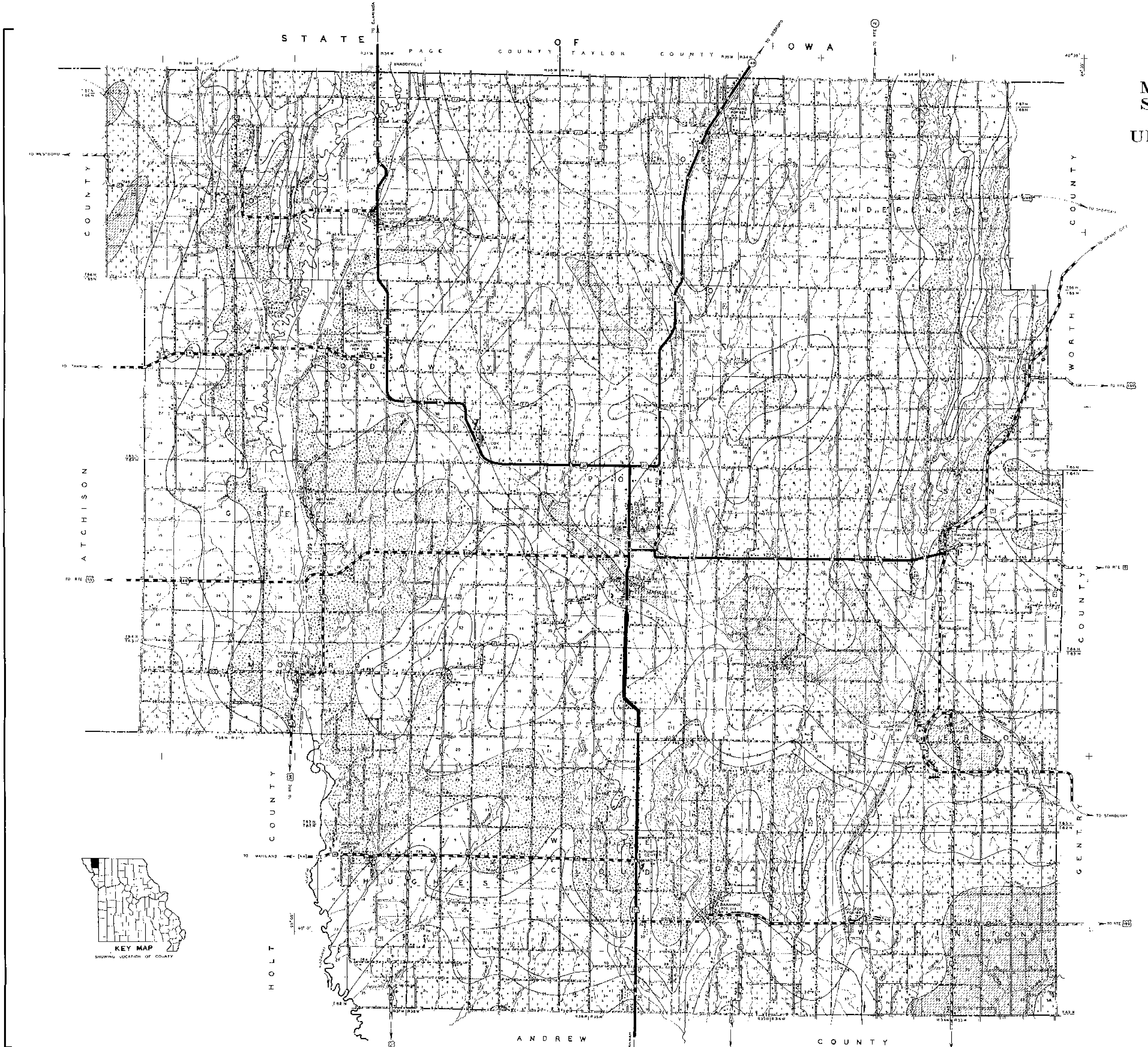
1959

MISSOURI GEOLOGICAL SURVEY & WATER RESOURCES

ROLLA, MO

THOS R. BEVERIDGE

STATE GEOLOGIST



LEGEND

THICKNESS IN FEET	WATER POSSIBILITIES IN GALLONS PER MINUTE
ALLUVIUM THICKNESS VARIABLE	0 - 500
0 - 50	5 10
50 - 100	
100 - 200	15
200 - 300	30
OVER 300	

BASE BY MO STATE HIGHWAY DEPT

SCALE

0 1 2 3 4 MILES

POLYCONIC PROJECTION

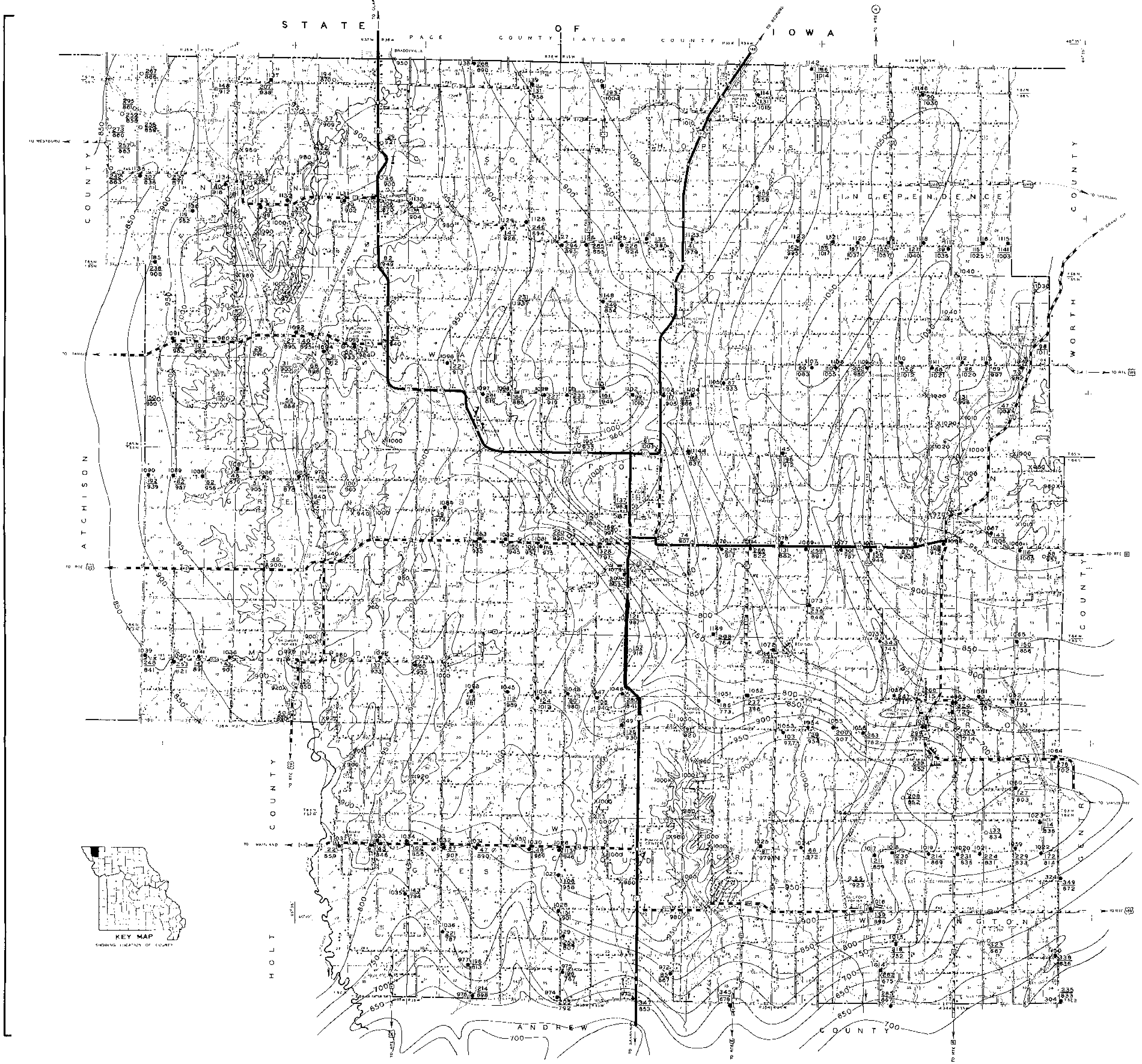


PLATE 2

MAP OF NODAWAY COUNTY SHOWING BEDROCK CONTOURS

BY
G. E. HEIM
J. A. MARTIN
W. B. HOWE

1959

MISSOURI GEOLOGICAL SURVEY & WATER RESOURCES
ROLLA, MO

THOS. R. BEVERIDGE
STATE GEOLOGIST

LEGEND

1234 ● M.G.S. TEST HOLE SHOWING TEST HOLE NO.

WATER WELL, OIL & GAS TEST, ETC.

987 X BEDROCK EXPOSURES AND ELEVATION

245 —— THICKNESS OF UNCONSOLIDATED MATERIAL
878 —— BEDROCK ELEVATION

CONTOUR INTERVAL = 50'

BASE BY MO. STATE HIGHWAY DEPT.

SCALE

0 1 2 3 4 MILES