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STATE OF SOUTH DAKOTA
JOE FOSS, GOVERNOR

STATE GEOLOGICAL SURVEY
E. P. ROTHROCK, STATE GEOLOGIST

REPORT OF INVESTIGATIONS

NO. 82

GEOLOGY AND HYDROLOGY
OF THE
PARKER - CENTERVILLE OUTWASH

BY

M. J. TIPTON

UNIVERSITY OF SOUTH DAKOTA
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GEOLOGY AND HYDROLOGY

OF THE

PARKER - CENTERVILLE OUTWASH

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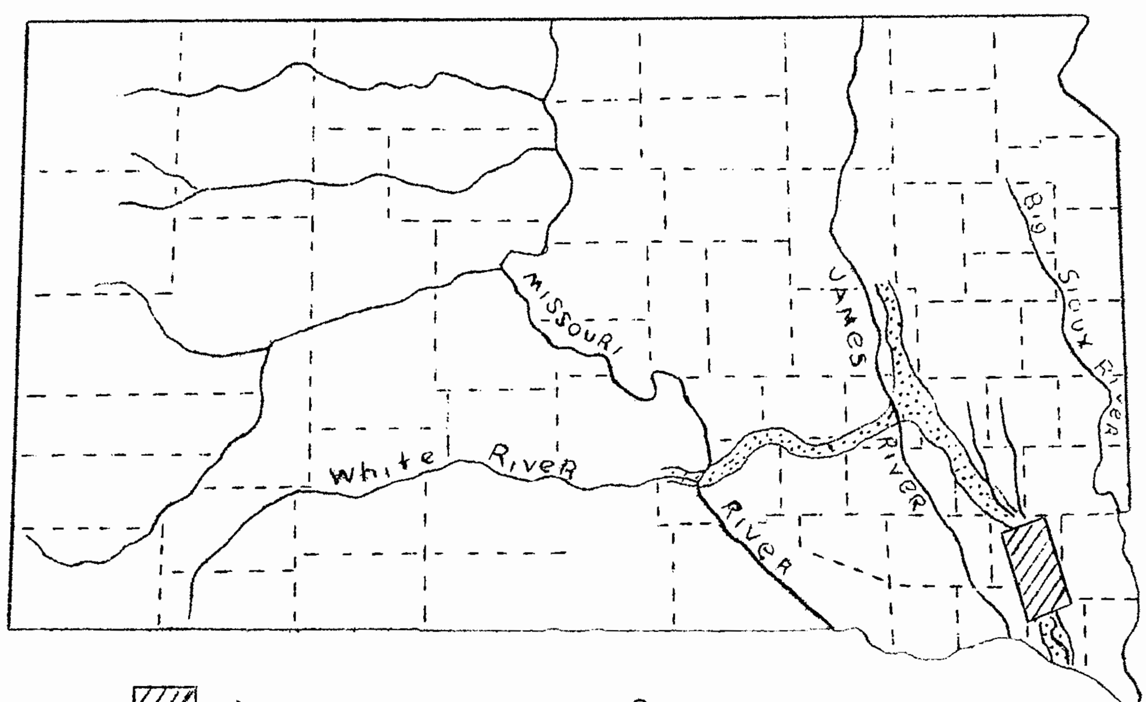
FIG. 1 - INDEX MAP



AREA COVERED BY THIS SURVEY

PRE-GLACIAL VALLEY OF WHITE RIVER

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GEOLOGY AND HYDROLOGY OF THE PARKER-CENTERVILLE OUTWASH

BY

M. J. TIPTON

INTRODUCTION

GENERAL STATEMENT

THE INVESTIGATION OF THE PARKER-CENTERVILLE OUTWASH WAS UNDERTAKEN BY THE STATE GEOLOGICAL SURVEY AS PART OF A PROGRAM TO DEVELOP THE SHALLOW WATER RESOURCES OF SOUTH DAKOTA. THE FREQUENT DRY SEASONS, WHICH HAVE BROUGHT ABOUT THE RECENT INTEREST IN SHALLOW WELL IRRIGATION, HAVE FOCUSED THE SURVEY'S ATTENTION ON SHALLOW WATER RESERVOIRS. THE PARKER-CENTERVILLE OUTWASH IS ONE OF THESE RESERVOIRS WHOSE DEVELOPMENT CAN BE OF GREAT VALUE TO THE STATE.

LOCATION AND AREA

THE AREA COVERED IN THIS REPORT LIES IN THE VERMILLION RIVER BASIN IN TURNER AND CLAY COUNTIES (FIG. 1). THE TOTAL AREA MAPPED ON THIS PROJECT COVERS ABOUT 160 SQUARE MILES, OF WHICH 66 SQUARE MILES ARE OCCUPIED BY THE OUTWASH RESERVOIR.

PURPOSE AND METHOD OF INVESTIGATION

THERE WERE TWO PURPOSES IN MAKING THIS INVESTIGATION: (1) TO MAP THE GEOLOGY OF THE RESERVOIR AND THE AREA IMMEDIATELY SURROUNDING, (2) TO DETERMINE THE SHALLOW WATER CONDITIONS PREVAILING IN THIS RESERVOIR.

THE FIELD WORK WAS DONE DURING THE SUMMER OF 1956. THE GEOLOGICAL FIELD PARTY INCLUDED THE WRITER AS GEOLOGIST, ROBERT SCHOON AS FIELD ASSISTANT, S. W. HOWELL AS GEOPHYSICIST AND DONALD JORGENSEN AND EUGENE FICK AS ASSISTANTS. GARY LARSON AND ROBERT MARTIN JOINED THE PARTY LATE IN THE SUMMER AND SERVED AS A DRILL AND SURVEYING CREW.

THE BOUNDARIES OF THE RESERVOIR WERE FIRST DETERMINED ON THE BASIS OF TOPOGRAPHY. THEN ELECTRIC SOUNDINGS WERE MADE WITH A RESISTIVITY GRADIOMETER TO DETERMINE THE THICKNESS OF THE SAND AND GRAVEL DEPOSITS IN THE RESERVOIR. THESE STATIONS WERE SET AT EVERY SECTION CORNER WITH A FEW INTERSPERSED WHERE NEEDED. A BRIEF HISTORY OF MOST OF THE DOMESTIC AND IRRIGATION

WELLS WAS OBTAINED AND ELEVATIONS WERE CARRIED TO ALL CRITICAL POINTS IN THE AREA BY PLANE-TABLE. TEST HOLES WERE DRILLED AT RANDOM POINTS TO CHECK THE INTERPRETATION OF THE RESISTIVITY SOUNDINGS AND TO GET A MORE DETAILED PICTURE OF THE SUBSURFACE GEOLOGY. ABOUT THE MIDDLE OF THE SUMMER, 15 OBSERVATION WELLS WERE DRILLED AT STRATEGIC POINTS ON THE OUTWASH TO KEEP AN ACCURATE CHECK ON THE FLUCTUATIONS OF THE WATER TABLE. THESE OBSERVATION WELLS WERE INSTALLED WITH THE COOPERATION OF THE GRIMSHAW AND BICE DRILLING COMPANY, WHO DRILLED THE WELLS WITHOUT CHARGE, AND THE STATE WATER RESOURCES COMMISSION WHO FINANCED THE COST OF THE PIPE AND EQUIPMENT. THE STATE GEOLOGICAL SURVEY CARRIED ELEVATIONS TO THESE WELLS AND HAS MADE MONTHLY READINGS OF THE WATER FLUCTUATIONS SINCE THAT TIME.

Previous Investigations

J. E. TODD (1903) INCLUDED THIS AREA IN THE MAPPING OF THE PARKER QUADRANGLE; AND MORE RECENTLY, R. F. FLINT (1955) MADE A RECONNAISSANCE STUDY OF THE GLACIAL DEPOSITS OF SOUTH DAKOTA EAST OF THE MISSOURI RIVER. THE SOUTH DAKOTA GEOLOGICAL SURVEY HAS ALSO HAD A LONG-STANDING INTEREST IN THIS AREA AND FOR THE PAST TWENTY YEARS HAS KEPT RECORDS OF THE WATER LEVEL IN TWO WELLS LOCATED IN IT.

Acknowledgments

THE WRITER IS DEEPLY INDEBTED TO DR. E. P. ROTHROCK, STATE GEOLOGIST, WHO CONCEIVED THE PROJECT AND UNDER WHOSE GUIDANCE IT WAS CARRIED OUT.

APPRECIATION IS ALSO EXPRESSED FOR THE KIND COOPERATION RECEIVED FROM THE WELL DRILLERS AND RESIDENTS OF THE PARKER-CENTERVILLE AREA.

SPECIAL THANKS ARE DUE THE MEMBERS OF THE FIELD PARTY FOR THEIR VALUABLE ASSISTANCE IN COMPILING THE DATA USED IN THIS REPORT AND TO DR. ALLEN F. AGNEW, DR. K. Y. LEE AND DR. ROBERT E. STEVENSON FOR THEIR MANY HELPFUL SUGGESTIONS.

GEOGRAPHY

Climate

THE AREA MAPPED LIES ON THE WESTERN EDGE OF THE HUMID CONTINENTAL BELT AND HAS A TYPICAL CONTINENTAL CLIMATE WITH HOT SUMMERS AND COLD WINTERS. THE AVERAGE GROWING SEASON IS 140 DAYS. DURING THE SUMMER, TEMPERATURES OF 100° F. ARE

NOT UNCOMMON; AND IN THE WINTER THE MERCURY IS WELL BELOW 0° F. ON MANY OCCASIONS. THE ANNUAL MEAN TEMPERATURE FROM 1938 TO 1956 WAS 47.7° F. (TABLE 1). ACCORDING TO RECORDS OF THE U. S. WEATHER BUREAU, THE ANNUAL PRECIPITATION FOR THIS AREA FROM 1938 TO 1956 AVERAGED 24.62 INCHES (TABLE 1). THE MAXIMUM PRECIPITATION OF 41.13 INCHES FELL IN 1941 AND THE MINIMUM OF 16.24 IN 1939.

POPULATION AND AGRICULTURE

THE PARKER-CENTERVILLE AREA IS QUITE THICKLY POPULATED, HAVING ABOUT 28 PEOPLE PER SQ. MILE, AND THE TOWNS ARE FAIRLY NUMEROUS BUT NOT LARGE (TABLE 2). FARMING IS THE CHIEF

TABLE 2

POPULATION OF TOWNS

TOWN	POPULATION (1950 CENSUS)
PARKER	1148
CENTERVILLE	1053
HURLEY	474
CHANCELLOR	193
DAVIS	153

OCCUPATION WITH CORN, ALFALFA, AND SMALL GRAINS AS THE MAJOR CROPS. SHEEP, CATTLE, AND HOGS ARE ALSO RAISED.

TWO DISTINCT SOIL TYPES ARE RECOGNIZED IN THE AREA MAPPED. TOWARD THE CENTER OF THE OUTWASH, THE SANDS AND GRAVELS ARE COVERED WITH A LIGHT SANDY LOAM TO A DEPTH OF FROM 10 TO 20 INCHES. THIS SOIL HAS HIGH PERMEABILITY, WHICH MEANS THAT WATERS WHICH FALL ON IT, EITHER FROM RAIN OR IRRIGATION, WILL PASS THROUGH IT READILY INTO THE RESERVOIR. THIS SOIL IS LOCALLY REFERRED TO AS THE "LIGHT SOIL". AROUND THE EDGE OF THE OUTWASH THE COVER CONTAINS MORE FINE MATERIAL AND WOULD BE CLASSED AS A SILT OR LIGHT CLAY LOAM. THIS SOIL IS DESIGNATED LOCALLY AS THE "HEAVY SOIL" AND HAS THICKNESSES OF FROM 36 TO 60 INCHES. THOUGH IT IS NOT AS PERMEABLE AS THE SO-CALLED LIGHT SOIL, IT STILL ALLOWS WATER TO PASS THROUGH IT WITH SUFFICIENT EASE TO PREVENT WATER LOGGING. THE HEAVY SOIL HAS BEEN THE MORE PRODUCTIVE OF THE TWO BECAUSE OF ITS ABILITY TO RETAIN MOISTURE LONGER. HOWEVER, WITH AN AMPLE SUPPLY OF WATER, THE LIGHT SOIL COULD POSSIBLY DO AS WELL.

GEOLOGY

TOPOGRAPHY

THE TOPOGRAPHY OF THIS REGION REFLECTS THE TWO MAIN GLACIAL AGENTS WHICH FORMED IT: ICE AND MELTWATER FROM THE ICE. THE MELTWATERS FORMED THE OUTWASH RESERVOIR AND THE ICE FORMED THE BOULDER-CLAY WHICH SURROUNDS THE RESERVOIR.

THE OUTWASH:- THIS OUTWASH RESERVOIR, CALLED "THE UNDERGROUND LAKE" BY LOCAL RESIDENTS, UNDERLIES SOME 40,000 ACRES (66 SQUARE MILES) ALONG THE VERMILLION VALLEY IN TURNER COUNTY. THE CITY OF PARKER IS AT THE NORTHWESTERN END OF THE RESERVOIR AND THE CITY OF CENTERVILLE AT THE SOUTHERN END. HURLEY LIES MIDWAY ON ITS SOUTHWESTERN EDGE, AND DAVIS LIES NEAR ITS CENTER. THESE ARE NOT THE LIMITS OF THE OUTWASH, HOWEVER, AS IT IS FOUND BOTH ABOVE AND BELOW THE AREA MAPPED.

BETWEEN PARKER AND DAVIS, THE OUTWASH HAS FILLED AN IRREGULARLY SHAPED FLAT DEPRESSION SOME SEVEN MILES IN WIDTH AND ELEVEN MILES LONG. FROM DAVIS TO CENTERVILLE, THE OUTWASH IS GEOLOGICALLY CALLED A VALLEY TRAIN AS IT IS CONFINED TO THE FAIRLY NARROW VERMILLION VALLEY, WHICH IS ABOUT A MILE WIDE IN THIS SECTION OF ITS COURSE.

THE BLUFFS OF THE VERMILLION VALLEY RISE STEEPLY ABOVE THE VALLEY BOTTOM UPSTREAM FROM PARKER AND DOWNSTREAM FROM DAVIS. BETWEEN THESE CITIES THE OUTWASH WIDENS GREATLY AND THE BLUFFS RISE SO GENTLY ABOVE THE FLAT OUTWASH SURFACE THAT IT TAKES CAREFUL OBSERVATION TO DETECT THE LINE OF DEMARKATION. THIS GENTLE SLOPE ON THE SOUTH AND WESTERN SIDES RISES ABOUT 20 FEET IN A MILE, AND THAT ON THE NORTH AND EASTERN SIDES ABOUT 10 FEET IN A MILE.

THE GRAVELS IN THIS RESERVOIR WERE POURED, BY THE MELTWATERS OF THE GLACIER, INTO A MORE OR LESS BASIN-SHAPED DEPRESSION WHICH MAY HAVE BEEN PART OF A PRE-GLACIAL VALLEY THAT CROSSED THIS PART OF SOUTH DAKOTA, (FIG. 1) AND (FLINT 1955, PLATE 7). SOME HILLS OR KNOBS OF BOULDER CLAY WERE PRESENT ON THE SURFACE OF THIS DEPRESSION BEFORE THE SANDS AND GRAVELS WERE INTRODUCED. THESE ARE NOW REFLECTED AS ISLANDS OF BOULDER CLAY SURROUNDED BY GRAVEL OUTWASH. A PERUSAL OF THE GEOLOGIC MAP SHOWS THAT SIX OF THESE HILLS CAME TO THE SURFACE.

FOUR SMALL ISLANDS, THE LARGEST OF WHICH COVERS ABOUT A QUARTER SECTION, LIE JUST NORTH OF DAVIS. A LARGER ONE, ABOUT A HALF SECTION IN AREA, LIES IN A BEND OF THE VERMILLION RIVER

TWO MILES SOUTHWEST OF CHANCELLOR. ANOTHER LARGE ONE COVERING APPROXIMATELY A SECTION EXTENDS WELL OUT INTO THE OUTWASH TWO MILES NORTH OF HURLEY. THESE ISLANDS OF BOULDER CLAY HAVE VERY LITTLE TOPOGRAPHIC EXPRESSION AS THEIR FLAT TOPS ARE ALMOST OR ENTIRELY LEVEL WITH THE TOP OF THE OUTWASH PLAIN.

LOWER UNDULATIONS DID NOT REACH THE SURFACE BUT CAUSED A THINNING OF THE GRAVELS AND SANDS OVER THEM. THESE ARE SHOWN AS FAR AS POSSIBLE ON THE CROSS-SECTIONS OF THE GEOLOGIC MAP (PLATE I) ACCOMPANYING THIS REPORT.

<u>MATERIAL SURROUNDING THE OUTWASH RESERVOIR</u>:- THE RESERVOIR IS SURROUNDED BY THE BLUFFS OF THE VERMILLION VALLEY. THESE BLUFFS ARE MADE OF BOULDER CLAY WHICH WAS DERIVED FROM THE ICE OF THE GLACIER. THIS MATERIAL, GEOLOGICALLY KNOWN AS TILL, IS A HETEROGENOUS MIXTURE OF SAND GRAINS, PEBBLES, COBBLES, AND BOULDERS IN A MATRIX OF CLAY. THIS TILL WAS FORCED BENEATH THE GLACIER ICE OR PARTLY LET DOWN FROM THE UPPER PARTS OF THE ICE AS IT MELTED OR EVAPORATED. AS A RESULT, THE SURFACE OF THE TILL IS VERY GENTLY UNDULATING WITH A FEW KETTLES, MARSHES AND CLOSED DEPRESSIONS AND IS TERMED GROUND MORAINE IN THIS REGION (PLATE I).

DRAINAGE

THE PRESENT DRAINAGE SYSTEM IS DIRECTLY CONTROLLED BY THE GLACIATION BUT MAY HAVE BEEN INDIRECTLY CONTROLLED BY A PREGLACIAL VALLEY OF THE WHITE RIVER PREVIOUSLY REFERRED TO (FIG. I).

THE MAIN STREAM IN THE AREA IS THE VERMILLION RIVER WHICH FLOWS ALONG THE EASTERN SIDE OF THE OUTWASH AND CONTINUES SOUTH IN A MEANDERING COURSE ACROSS THE VALLEY TRAIN. IT EVENTUALLY EMPTIES INTO THE MISSOURI RIVER NOT FAR FROM VERMILLION. THIS RIVER ORIGINATES 60 MILES NORTH OF THE MAPPED AREA AND DRAINS SOME 8000 SQUARE MILES OF PLAINS BETWEEN THE JAMES AND BIG SIOUX RIVERS (FIG. I). THE EAST AND WEST FORKS OF THE VERMILLION RIVER JOIN ON THE OUTWASH PLAIN JUST EAST OF PARKER. THERE ARE MANY SMALL INTERMITTENT STREAMS WHICH FLOW INTO THE RIVER FROM BOTH SIDES, THE LARGEST BEING TURKEY RIDGE CREEK, WHICH DRAINS THE EASTERN FLANK OF TURKEY RIDGE TO THE WEST. A LARGE DAM ON THE VERMILLION RIVER AT CENTERVILLE AND SEVERAL SMALLER DAMS ALONG THE COURSE OF THE RIVER HELP TO STABILIZE THE SHALLOW GROUND WATER LEVEL.

STRATIGRAPHY

THE FORMATIONS EXPOSED IN THIS AREA BELONG TO THE TWO

GEOLOGIC SYSTEMS AT THE EXTREME ENDS OF THE GEOLOGIC TIME-ROCK CHART: THE PRE-CAMBRIAN SIOUX FORMATION AND THE QUATERNARY WISCONSIN DRIFT AND RECENT ALLUVIAL DEPOSITS[1] (TABLE 3).

TABLE 3

GEOLOGIC TIME-ROCK CHART
OF THE PARKER-CENTERVILLE OUTWASH

SYSTEM	SERIES	STAGE	SUB-STAGE	FORMATION
QUATERNARY	RECENT			ALLUVIUM
	PLEISTOCENE	WISCONSIN	CARY	OUTWASH VALLEY TRAIN TILL
		UNCONFORMITY		
PRE-CAMBRIAN				SIOUX QUARTZITE

PRE-CAMBRIAN DEPOSITS

<u>SIOUX</u> <u>FORMATION</u>:- THE SIOUX QUARTZITE FORMATION IS A SEDIMENTARY ROCK CONSISTING OF WELL-SORTED, ROUNDED, PINK GRAINS OF QUARTZ SAND WELL CEMENTED BY SILICA.

[1] THERE MAY BE CHALK FROM THE CRETACEOUS NIOBRARA FORMATION NEAR THE SURFACE IN THE SOUTHWESTERN PORTION OF THE AREA MAPPED. THE ONLY EVIDENCE OF THIS, HOWEVER, WAS FROM FARMERS WELL LOGS (APPENDIX).

The only outcrop of the Sioux formation is in the SE$\frac{1}{4}$, Sec. 14, T99N., R53W., and covers an area of a few square yards. The outcrop has several glacial striations on its surface which indicate that the movement of the ice was in a southwesterly or a northeasterly direction.

Pleistocene Deposits

During the Wisconsin glacial stage, eastern South Dakota was completely covered by ice during the Iowan and Cary substages and partially covered during the Tazewell and Mankato substages. In the Parker-Centerville area, only the Cary substage of glaciation was recognized; however, the Mankato substage may also be present.

Cary Till:- The Cary till (boulder clay) covers the area on both the east and west sides of the outwash reservoir. Its surface is slightly rougher on the west side than on the east.

The till is nowhere exposed in more than a ten foot cut so no accurate surface measurement of its thickness could be made. However, from drill hole information, it can be estimated at being between 30 and 40 feet thick.

The till is composed of sediments ranging in size from boulders to clay, with the largest percentage being silt and clay (table 8). These sediments consist of igneous and metamorphic rocks with Paleozoic limestones and dolomites (similar to those outcropping in Canada) and a large percentage of Niobrara chalk (derived locally).

This till also underlies the sand and gravel of the reservoir and appears as "blue clay" in wells that are drilled through the gravels.

Mankato Till:- In his reconnaissance, Flint (1955) mapped the deposits in the northwest corner of this area as Mankato substage of glaciation and the remainder as Cary substage; however, no evidence of the Mankato age could be found. There is no apparent topographic break between the two areas, nor did the laboratory analysis of the tills suggest any means of differentiating them. In addition to this evidence, Zumberge and Wright (1956, p75-78) have shown by radiocarbon dating that the till at the Mankato type locality in Minnesota is actually Cary in age. Consequently, the entire Parker-Centerville area was mapped as Cary till.

CARY OUTWASH AND VALLEY TRAIN:- THE SEDIMENTS OF THE OUTWASH AND VALLEY TRAIN UNDERLIES AN AREA OF ABOUT 66 SQUARE MILES AND HAVE AN AVERAGE THICKNESS OF 45 FEET, AS DETERMINED BY TEST HOLES AND RESISTIVITY SOUNDINGS (APPENDIX). THE DEEPEST PORTION IS OVER 90 FEET THICK (SEC. 4, T98N., R53W.) AND THE THINNEST PARTS ARE AROUND THE EDGES. THERE IS AN ESTIMATED 3,210,662,400 CUBIC YARDS OF SAND AND GRAVEL IN THE OUTWASH AND VALLEY TRAIN COMBINED.

THE ORIGIN OF THESE OUTWASH SEDIMENTS IS NOT OBVIOUS AS THERE ARE NO PROMINENT END MORAINES IN THE AREA FROM WHICH THEY COULD HAVE BEEN DERIVED. IT IS POSSIBLE THAT THE END MORAINES MAY HAVE BEEN DESTROYED BY A LARGE VOLUME OF MELT-WATER. THIS WOULD HELP TO EXPLAIN THE UNUSUALLY GREAT VOLUME OF SEDIMENTS IN THIS OUTWASH AS COMPARED TO OTHER OUTWASHES IN THE AREA.

PROBABLY THE SANDS AND GRAVELS WERE WASHED INTO THE BASIN DIRECTLY FROM A RECESSIONAL ICE FRONT WHICH LAY ALONG THE NORTH-WESTERN MARGINS OF THE PRESENT OUTWASH BODY. THIS PROBABILITY IS SUPPORTED BY THE GREATER THICKNESS OF THE OUTWASH SEDIMENTS ALONG THIS NORTHWESTERN PORTION OF THE OUTWASH; AND ALSO BY THE PRESENCE OF TILL OVERLYING THE GRAVELS IN SECTIONS 4, 5, 9, AND 10, T98N., R53W. THE POSITION OF THE TILL IS PROBABLY DUE TO SLUMPING WHICH OCCURRED AT THE MARGIN OF THE ICE FRONT, CREATED BY UNDERCUTTING OF THE TILLS BY MELTWATER. ANOTHER FACTOR LENDING SUPPORT TO THIS EXPLANATION IS THE PRESENCE OF MANY OUTWASH PITS IN THIS NORTHWESTERN AREA. THESE PITS ARE THE RESULT OF LARGE BLOCKS OF ICE BREAKING OFF FROM THE MAIN ICE FRONT AND MELTING AFTER THE OUTWASH SEDIMENTS WERE DE-POSITED AROUND THEM.

THE SEDIMENTS OF THE VALLEY TRAIN WERE DERIVED FROM THE SAME SOURCE AS THE SEDIMENTS FOR THE MAIN OUTWASH RESERVOIR AS FAR SOUTH AS CENTERVILLE. AS CAN BE SEEN ON PLATE I THE VAL-LEY TRAIN WIDENS SOUTH OF CENTERVILLE AND THERE IS EVIDENCE IN THE LABORATORY ANALYSIS OF THE SEDIMENTS TO INDICATE THAT THE SANDS AND GRAVELS WHICH FILL THE VALLEY FROM THE WIDENED PORTION SOUTH HAD A SEPARATE SOURCE FROM THE SANDS AND GRAVELS OF THE OUTWASH RESERVOIR. HOWEVER, THERE ARE NO END MORAINES NEAR THIS WIDENED PORTION OF THE VALLEY TRAIN FROM WHICH THESE SEDIMENTS COULD HAVE BEEN DERIVED JUST AS THERE ARE NO END MORAINES NEAR THE MAIN OUTWASH BODY.

LABORATORY ANALYSIS OF THE TILL AND OUTWASH:- SEVERAL SAMPLES OF THE TILL AND OF THE OUTWASH SEDIMENTS WERE COLLECTED AT AVAILABLE EXPOSURES AND LABORATORY TESTS SUCH AS SIZING, SORTING and composition were made. The laboratory tests were made to determine the environment of the sediments as this environment directly affects the occurrence and movement of water contained in these sediments. It should be kept in mind that these samples were collected at available exposures only and therefore do not show the conditions of the deeper portions of the till and outwash.

The composition of the outwash sands and gravels were determined by pebble counts and were found to consist mainly of limestone, dolomite and granite with lesser amounts of sandstone, shale, chert and greenstone. The composition of these sands and gravels is very similar to that of the Cary tills (Table 4) as is only natural being that both were derived from the same glacier. There are two notable exceptions, however, as almost no chalk is present in the outwash sediments while the tills contain up to 77% chalk (Table 4). This is probably due to the abrasive action of the meltwaters on the outwash sediments. The other exception is that many Sioux quartzite boulders are scattered over the surface of the till, whereas no Sioux quartzite pebbles were found in either the till or outwash sediments. This is probably due to the short distance of transport from the Sioux Ridge north of Parker to the area of deposit, which does not allow time for the abrasive action of the ice to break the boulders into smaller particles.

The textural properties of the outwash and till sediments were determined by mechanical analysis, using the Wentworth's size scale. The results of the mechanical analysis appear as

Wentworth's Size Classification

Grade Limits Diameter, Millimeters	Name of Particles
Above 256	Boulder
256 to 64	Cobble
64 to 4	Pebble
4 to 2	Granule
2 to 1	Very coarse sand
1 to 1/2	Coarse sand
1/2 to 1/4	Medium sand
1/4 to 1/8	Fine sand
1/8 to 1/16	Very fine sand
1/16 to 1/256	Silt
Below 1/256	Clay

HISTOGRAMS IN FIGURES 2 AND 3. A HISTOGRAM IS A BLOCK DIAGRAM WHICH SHOWS THE PERCENTAGE OF GRAIN WEIGHT IN EACH OF THE GRADE SIZES; AND FROM THE HISTOGRAM DATA, THE CUMULATIVE CURVE (FIGS. 4 & 5) IS MADE BY ADDING THE WEIGHT PERCENTAGES OF SUCCESSIVE GRADES AND THEN DRAWING A SMOOTH CURVE THROUGH THE POINTS. BY MEANS OF THE CUMULATIVE CURVE, THE 25TH AND 75TH QUARTILES AND THE 50TH PERCENTILE ARE FOUND. THE 50TH PERCENTILE ARE FOUND. THE 50TH PERCENTILE IS FOUND BY FOLLOWING THE 50 PERCENT LINE ON THE GRAPH TO THE RIGHT UNTIL IT INTERCEPTS THE CUMULATIVE CURVE AND THEN READING THE VALUE ON THE PHI SCALE AT THE BASE. THIS READING IS THEN CONVERTED TO MILLIMETERS BY MEANS OF A CONVERSION SCALE. THE 50TH PERCENTILE VALUE IS THE MEDIAN DIAMETER, WHICH IS THE AVERAGE GRAIN DIAMETER OF THE SEDIMENTS. THE 25TH AND 75TH QUARTILES ARE FOUND IN THE SAME MANNER EXCEPT THAT THE 25 AND 75 PERCENT LINES ARE USED. FROM THIS INFORMATION THE SORTING COEFFICIENT (So), WHICH IS DEFINED AS THE SQUARE ROOT OF THE RATIO OF THE FIRST QUARTILE TO THE THIRD QUARTILE ($So = \sqrt{Q_1 Q_3}$), CAN BE CALCULATED.

THE SORTING COEFFICIENT HAS A DIRECT RELATIONSHIP TO THE PERMEABILITY OF THE SEDIMENT. IN GENERAL, THE BETTER THE SORTING, THE BETTER THE PERMEABILITY; AND CONVERSELY, THE POORER THE SEDIMENT IS SORTED THE POORER ALSO IS ITS PERMEABILITY. WELL SORTED SEDIMENTS HAVE SORTING COEFFICIENTS LESS THAN 2.5; MODERATELY SORTED SEDIMENTS RANGE FROM 2.5 TO 4.0; AND POORLY SORTED SEDIMENTS RANGE ABOVE 4.0.

THE SAMPLES OF SAND AND GRAVEL SHOW SORTING COEFFICIENTS BETWEEN 2.3 AND 3.5 (TABLE 5), THUS BEING MODERATELY TO WELL SORTED AND HAVING A GENERALLY HIGH DEGREE OF PERMEABILITY; ON THE OTHER HAND, THE SAMPLES OF TILL SHOW SORTING COEFFICIENTS BETWEEN 6.3 AND 16.1 (TABLE 5), THUS BEING POORLY SORTED AND HAVING A LOW DEGREE OF PERMEABILITY.

THE MEDIAN DIAMETER OF THE SEDIMENTS IS DIRECTLY RELATED TO THE STRENGTH OF THE CURRENT TRANSPORTING THE SEDIMENTS AND THE DISTANCE THAT THE SEDIMENTS HAVE TRAVELED FROM THE SOURCE. IN GENERAL, THE LARGER THE MEDIAN DIAMETER OF THE SEDIMENT THE CLOSER IT IS TO ITS SOURCE AND THE STRONGER THE CURRENT OF THE TRANSPORTING AGENT.

IN THE GRAVEL SAMPLES STUDIED, THE MEDIAN DIAMETER OF THE SAMPLES TAKEN NEAR THE SOURCE OF THE OUTWASH IS SLIGHTLY OVER 4 MILLIMETERS WHEREAS A SAMPLE TAKEN NEAR THE TOWN OF DAVIS (ABOUT EIGHT MILES FROM THE SOURCE), HAS A MEDIAN DIAMETER OF 1 MILLIMETER. A SAMPLE WHICH WAS COLLECTED SOUTH OF CENTERVILLE

(Sec. 25, T95N., R53W.) has a median diameter of 3.5. This lends support to the theory that the gravels below Centerville had a separate source than the one for the main outwash body.

The pebbles of the outwash and valley train are, in general, angular to sub-round in the northwest part of the area and gradually become more rounded as they are traced in a southeasterly direction along the outwash body and down the valley train away from the source. However the pebbles and boulders in the widened portion of the valley train south of Centerville (Plate I) become more angular; this correlates with the anomalous median diameter and sorting there, thus reflecting a separate source for the sediments south of this region.

Recent Sediments

Alluvium:- The alluvium, which was deposited by streams, is confined to the small flood plains along the main stream and its tributaries. It consists of silt and clay size particles with some grains and lenses of sand. The alluvium is characterized by faint cross-bedding and slight laminar structure, thus showing that it has been deposited chiefly by water.

HYDROLOGY

Shallow Ground Water

The shallow ground water in this area is contained in the glacial sediments, with the largest percentage of available water coming from the sand and gravel portion. The sand and gravel deposits of the outwash and valley train are considered a good storage environment for the shallow water as it was established in the laboratory analysis that they are very permeable. Water can move through the sand and gravel without much difficulty, hence they furnish the main water supply to shallow wells. The sand lenses which occur in the glacial till also provide small reservoirs for the storage of shallow water. However, due to the high percentage of silt and clay contained in the surrounding tills, (Table 8) the water percolates very slowly through them; thus they furnish only small local supplies of water.

The source of shallow ground water in this region is from precipitation in the form of rain and snow. Part of this precipitation is lost through surface runoff, evaporation, and transpiration; however, the remainder percolates downward through the topsoil and recharges the shallow ground water supply.

THE WATER TABLE AND MOVEMENT OF SHALLOW GROUND WATER

THE WATER TABLE IS DEFINED AS THE UPPER SURFACE OF THE ZONE OF SATURATION, EXCEPT WHERE THAT SURFACE IS FORMED BY AN IMPERMEABLE BODY (MEINZER 1923, P 30). THIS WATER TABLE IN THE SAND AND GRAVEL RESERVOIR UNDER DISCUSSION IS AT AN AVERAGE DEPTH OF ABOUT 10 FEET OVERALL. THERE ARE A FEW DEPRESSIONS IN THE RESERVOIR WHERE THE SURFACE OF THE WATER TABLE CAN BE SEEN SUCH AS AT MUD LAKE NEAR HURLEY, AND IN THE WATER IN THE BOTTOM OF GRAVEL PITS SUCH AS THE ONE ON THE O'KEFFE FARM IN SEC. 3, T18N., R53W.

THE WATER TABLE IS NOT A LEVEL SURFACE SUCH AS ON A LAKE BUT RATHER A SLOPING SURFACE WHICH CONFORMS GENERALLY TO THE TOPOGRAPHY. MOREOVER, THE WATER TABLE DOES NOT STAY AT A FIXED ELEVATION BUT IS HIGHER IN MOIST SEASONS THAN IN DRY AND EVEN FLUCTUATES FROM MONTH TO MONTH. (SEE FIGURES 6 & 7 AND TABLE 9).

WATER IN AN UNDERGROUND RESERVOIR PERCOLATES FROM THE HIGHER PARTS OF THE WATER TABLE TO THE LOWER PARTS AND THE RATE AT WHICH THIS PERCOLATION TAKES PLACE DEPENDS ON THE PERMEABILITY OF THE MATERIALS THROUGH WHICH THE WATER IS PASSING. IT IS FOR THIS REASON THAT IT IS POSSIBLE TO PUMP LARGE QUANTITIES OF WATER FROM THE VERY PERMEABLE SANDS AND GRAVELS SUCH AS OCCUR IN THE OUTWASH WHILE ONLY SMALL AMOUNTS CAN BE OBTAINED FROM WELLS WHICH OCCUR IN THE SURROUNDING BOULDER CLAY.

RECHARGE

RECHARGE IS THE ADDITION OF WATER TO THE UNDERGROUND RESERVOIR AND IN THIS AREA THERE ARE THREE MAIN SOURCES: RAINFALL, RUNOFF FROM THE SURROUNDING HILLS, AND STREAMS ENTERING THE AREA. THERE IS ALSO A MINOR AMOUNT OF RECHARGE FROM PONDS AND SWAMPS AND BY SUBSURFACE UNDERFLOW.

THE RECHARGE BY RAINFALL DEPENDS UPON THE ANNUAL PRECIPITATION WHICH HAS AVERAGED ABOUT 24 INCHES A YEAR IN THE PAST 20 YEARS. (TABLE 1). ONE INCH OF RAINFALL ON ONE SQUARE MILE OF LAND SURFACE IS EQUIVALENT TO 2,323,000 CUBIC FEET OF WATER (FOX 1949, P 11) OR MORE THAN 17 MILLION (U.S.) GALLONS OF WATER. THIS MULTIPLIED BY THE ANNUAL PRECIPITATION OF 24 INCHES AMOUNTS TO ABOUT 408 MILLION GALLONS OF WATER PER SQUARE MILE, OR MORE THAN 26 BILLION GALLONS FOR THE WHOLE RESERVOIR. MOST OF THIS WATER IS ABSORBED BY THE RESERVOIR SINCE THE SURFACE IS VERY FLAT AND THE SOILS ARE SANDY OR LOAMY. THUS, IN

SPITE OF THE TRANSPIRATION OF A PORTION OF THIS WATER INTO THE AIR BY PLANTS GROWING ON THE RESERVOIR, AN ACCUMULATION OF FROM A FOOT AND ONE HALF TO TWO FEET OF WATER PER YEAR COMES DIRECTLY FROM RAINFALL.

THE SECOND MAIN SOURCE OF RECHARGE FOR THE RESERVOIR COMES FROM RUNOFF ON THE SURROUNDING SLOPES. THESE SLOPES ARE UNDERLAIN BY TILL AND IN TIMES OF HEAVY RAIN, A LARGE PROPORTION OF THE WATER FALLING ON THEM RUNS OVER THE SURFACE AND INTO THE RESERVOIR. IT IS HARD TO ESTIMATE JUST HOW MUCH OF THIS WATER REACHES THE RESERVOIR; HOWEVER, ASSUMING THAT THE RUNOFF AMOUNTED TO ONLY ONE-TENTH OF THE PRECIPITATION WHICH FELL ON THESE SLOPES, THIS WOULD PROVIDE A SOURCE OF RECHARGE OF 816 MILLION GALLONS OF WATER PER YEAR.

THE THIRD MAIN SOURCE OF RECHARGE COMES FROM THE STREAMS FLOWING ONTO THE OUTWASH PLAIN. THE VERMILLION RIVER, BEING THE LARGEST STREAM, PROVIDES MOST OF THE RECHARGE OBTAINED IN THIS MANNER AND IS PERHAPS THE RESERVOIR'S GREATEST SOURCE OF WATER IN DRY TIMES. THIS RIVER CARRIES THE RUNOFF FROM AN AREA OF ABOUT 8000 SQUARE MILES NORTH OF THE OUTWASH AND PART OF THE RAINFALL FALLING IN THIS REGION EVENTUALLY REACHES THE RESERVOIR. THE RIVER LEVEL IN THE NORTHERN PART OF THE OUTWASH IS FROM 3 TO 5 FEET ABOVE THE WATER LEVEL IN THE RESERVOIR SO IT IS SAFE TO ASSUME THAT PART OF THIS WATER PERCOLATES DOWNWARD, HOWEVER, HERE AGAIN IT IS HARD TO SAY JUST HOW MUCH WATER IS OBTAINED IN THIS MANNER AS THERE HAS BEEN NO GAUGING OF THIS STREAM ABOVE THE OUTWASH. A GAUGE STATION, SEVEN MILES SOUTH OF CENTERVILLE, SHOWED THAT AN AVERAGE OF 102 MILLION GALLONS OF WATER FLOW THROUGH THE VERMILLION RIVER DAILY. (WELLS, 1952, P 488).

THERE WOULD ALSO BE A MINOR SOURCE OF RECHARGE FROM PONDS AND SWAMPS IN THE AREA BUT SINCE THEIR WATER SUPPLY IS DEPENDENT ON THE PRECIPITATION OF THE IMMEDIATE AREA, IT HAS BEEN INCLUDED IN THE RAINFALL RECHARGE FIGURE OF 26 BILLION GALLONS GIVEN ABOVE.

SUBSURFACE UNDERFLOW WOULD PROVIDE STILL ANOTHER MINOR SOURCE OF RECHARGE; BUT BEING THAT THE SURROUNDING SUBSURFACE SEDIMENTS ARE COMPOSED OF GLACIAL TILLS, WHICH HAVE A LOW PERMEABILITY, WATER PERCOLATING THROUGH THEM INTO THE RESERVOIR COULD PROVIDE ONLY A COMPARATIVELY SMALL AMOUNT OF RECHARGE.

OBSERVATION OF WELLS IN THE OUTWASH (FIGURE 7) AND IN THE SURROUNDING TILLS (FIGURE 6) SHOW THAT THE WATER TABLE HAS

FLUCTUATED MARKEDLY WITH THE SEASONS IN THE PAST 20 YEARS, BEING HIGHEST IN SPRING AND LOWEST IN EARLY WINTER. ITS EXACT POSITION IS DETERMINED BY THE AMOUNT OF PRECIPITATION WHICH FELL DURING THE PART OF THE YEAR IN WHICH THE READINGS WERE MADE. SPRING RAINS AND MELTING SNOW RAISE THE WATER TABLE, WHILE LACK OF RAIN AND FREEZING OF THE SOIL IN THE FALL AND WINTER LOWER IT. AN ORDINARY YEAR SEES A SEASONAL FLUCTUATION OF ABOUT 4 FEET IN THE BOULDER CLAY AND ABOUT 3 FEET IN THE RESERVOIR ACCORDING TO THE 20 YEAR RECORD ON THE OBSERVATION WELLS (FIGURES 6 & 7). IT IS NOTEWORTHY THAT THE LEVELS OF THE RESERVOIR DO NOT FLUCTUATE AS MUCH AS THOSE ON THE SURROUNDING UPLANDS. THIS IS DUE LARGELY TO THE RECHARGE FROM THE VERMILLION RIVER MENTIONED ABOVE.

DISCHARGE

DISCHARGE IS THE LOSS OF WATER FROM THE RESERVOIR AND IS ACCOMPLISHED BY NATURAL DISCHARGE AT THE SURFACE OR BY PUMPING FROM WELLS. EVEN WITHOUT PUMPING THERE IS CONSIDERABLE WATER LOSS FROM THE RESERVOIR DUE TO NATURAL DISCHARGES SUCH AS SEEPAGE, EVAPORATION, AND TRANSPIRATION THROUGH PLANTS.

A STUDY OF THE ACCOMPANYING MAP (PLATE II) WILL SHOW THAT THE WATER TABLE SLOPES SOUTHEAST, THAT IS DOWNSTREAM, OVER THE ENTIRE RESERVOIR. THIS MEANS THAT THE WATER IS PERCOLATING DOWN THIS SLOPE AND SEEPING INTO THE VERMILLION RIVER WHICH IS LOWER AT THE SOUTH END OF THE OUTWASH THAN AT THE NORTH END. THE SLOPE OF THIS WATER SURFACE IS LOW, AMOUNTING TO ABOUT FIVE FEET PER MILE OR A GRADE OF ONE FOOT IN EVERY 1056 FEET. THIS IS ABOUT FIVE TIMES THE SLOPE OF THE MISSOURI RIVER AND WOULD MAKE AN OPEN STREAM FLOW QUITE RAPIDLY. HOWEVER, IN GRAVEL IT CAUSES ONLY A SLOW PERCOLATION, BECAUSE OF THE FRICTION DEVELOPED IN FLOWING THROUGH THE SMALL OPENINGS BETWEEN THE SAND AND GRAVEL GRAINS.

WATER MAY ALSO BE LOST THROUGH NATURAL DISCHARGE FROM THE RESERVOIR AT THE SURFACE BY EVAPORATION INTO THE ATMOSPHERE AND TRANSPIRATION THROUGH PLANTS. THE AMOUNT OF WATER LOST BY EVAPORATION IS DEPENDENT ON THE VAPOR PRESSURE OF THE WATER SURFACE, VAPOR PRESSURE OF THE AIR, WIND MOVEMENT, AND SALINITY (BLAIR 1948, P 48). THE AMOUNT OF WATER LOST BY TRANSPIRATION THROUGH PLANTS IS DEPENDENT ON ATMOSPHERIC HUMIDITY, AIR MOVEMENT, AIR TEMPERATURE, INTENSITY OF LIGHT AND SOIL CONDITIONS. (ROBBINS AND WEIER, 1950, P 172-173). BECAUSE SO MANY VARIABLE FACTORS CONTROL THE AMOUNT OF WATER LOST BY EVAPORATION AND TRANSPIRATION, IT IS DIFFICULT TO ESTIMATE EXACTLY HOW MUCH IS LOST IN THIS MANNER.

THE MAIN DISCHARGE OF THIS RESERVOIR IS ACCOMPLISHED BY PUMPING FROM DOMESTIC, CITY AND IRRIGATION WELLS.

THE IRRIGATION WELLS PROBABLY USE THE LARGEST AMOUNT OF WATER; HOWEVER AN ACCURATE FIGURE OF THE AMOUNT OF WATER THEY USE IS NOT AVAILABLE, AS NONE OF THE WELLS HAVE GAUGES. THEY PUMP 300 TO 1500 GALLONS OF WATER PER MINUTE WHEN OPERATING BUT NOT ALL OF THIS WATER IS LOST AS SOME OF IT RETURNS TO THE RESERVOIR BY SEEPAGE AND CAN BE RECIRCULATED.

HURLEY IS THE ONLY CITY IN THE AREA WHICH DRAWS ITS WATER SUPPLY FROM THE OUTWASH AND A RECORD FROM NOVEMBER 1955 TO NOVEMBER 1956 SHOWS THAT IT USED 22,323,400 GALLONS OF WATER (TABLE 9).

DOMESTIC WELLS ACCOUNT FOR THE REMAINDER OF THE WATER WHICH IS DISCHARGED FROM THE RESERVOIR THROUGH WELLS. MOST OF THE RESIDENTS WHO LIVE ON THE OUTWASH PLAIN DRAW THEIR DOMESTIC SUPPLIES FROM THE OUTWASH RESERVOIR. THE TOTAL VOLUME OF WATER USED BY THEM HOWEVER, IS PROBABLY LESS THAN THAT USED BY THE CITY OF HURLEY ABOVE.

THE RESIDENTS WHO LIVE ON THE TILL SURROUNDING THE OUTWASH DRAW THEIR WATER SUPPLIES FROM THE TILL OR FROM THE FRACTURED SURFACE OF THE SIOUX QUARTZITE. SOME OF THE WELLS IN THE SOUTHWESTERN PORTION OF THE AREA MAPPED MAY DRAW WATER FROM THE NIOBRARA CHALK. THIS POSSIBILITY WAS NOT INVESTIGATED FURTHER DURING THE PRESENT STUDY, AS THE WATER OBTAINED FROM THE CHALK, AS WELL AS THE WATER OBTAINED FROM THE TILL AND QUARTZITE, IS ENTIRELY SEPARATE FROM THE OUTWASH AND DOES NOT AFFECT THE DISCHARGE OF THE OUTWASH RESERVOIR.

ESTIMATES OF WATER STORAGE OF THE RESERVOIR

IT HAS BEEN PREVIOUSLY ESTIMATED THAT THERE ARE SOME 3,210,662,400 CUBIC YARDS OF GRAVEL IN THE RESERVOIR. THE AMOUNT OF WATER STORED IN THE RESERVOIR IS DEPENDENT UPON THE POROSITY OF THIS SAND AND GRAVEL. THE POROSITY OF SEDIMENTS OF THIS TYPE USUALLY RANGES FROM 25% TO 45%. THEREFORE, BY TAKING THE TOTAL AMOUNT OF SAND AND GRAVEL IN THE RESERVOIR; SUBTRACTING THE TOP TEN FEET, WHICH IS THE AVERAGE DEPTH TO WATER, AND USING A CONSERVATIVE POROSITY OF 30%, THE AMOUNT OF WATER STORED IN THE SATURATED PORTION OF THE RESERVOIR IS ESTIMATED AT 144,897,984,000 GALLONS. THIS IS APPROXIMATELY 19,319,731,000 CUBIC FEET OR 433,520 ACRE FEET OF WATER, WHICH IS ABOUT 12 AND ONE-HALF TIMES AS MUCH WATER AS IS STORED IN THE BASIN OF LAKE KAMPESKA NEAR WATERTOWN WHEN THE LAKE IS FULL.

It should be kept in mind that the storage capacity of the reservoir cannot be figured exactly due to the non-uniformity of the textural properties of the outwash sediments. Therefore, the figures given above are conservative estimates.

Quality of the Water

Five samples of water were collected by the field party and analyzed by the State Chemical Laboratory. Four of the samples were collected from irrigation wells on the outwash and the fifth was collected from a domestic well located on the till. These analysis appear in Table 6. The five samples were also classified by the State Chemical Laboratory according to their suitibility for irrigation as follows: Class I - excellent to good, Class II - good to injurious, Class III - injurious to unsatisfactory. Samples I and 2 are placed in Class I; samples 3 and 4 in Class II and sample 5 in Class III. Samples 3 and 4 are quite high in sulfate content which places them in Class II. These high sulfate concentrations would be partially counteracted by the high calcium content thus making them satisfactory for irrigation purposes. The fifth sample contained such a high amount of sulfate that it was placed in Class III, however it is not used for irrigation.

The only other point of interest in the water analysis was the extreme hardness ($CaCO_3$ content) of all the samples. Any water that contains more than 130 parts per million of calcium carbonate ($CaCO_3$) is hard water (Bennison 1947, p 436). The 5 samples contained 316-1011 parts per million of $CaCO_3$, making them very hard; this does not affect their use for irrigation.

The variability in the quality of the water samples reflects the nature of the sediments in which it occurs or through which it has passed. Water, in passing through sediments, dissolves out many compounds and elements from them. When the sediments are sand and gravel there is also a filtering action which removes many compounds from the water. Thus a combination of this dissolving and filtering, added to the variability of the sediments themselves, will cause a change in the chemical composition of the water such as occurs in the five samples studied.

Irrigation

Future Wells:- There are enough water-bearing sediments in this area for irrigation wells to be located at any point on the

OUTWASH PLAIN AS LONG AS THEY ARE NOT PLACED TOO CLOSE TO THE EDGE OR TOO NEAR THE ISLANDS OF TILL WHERE THE OUTWASH SEDIMENTS ARE THIN. IN THIS AREA ONE IRRIGATION WELL WILL SUPPLY WATER TO APPROXIMATELY ONE-QUARTER SECTION OF LAND UNDER NORMAL CONDITIONS. IF THE WELL IS LOCATED IN THE CENTER OF THE QUARTER, IT WILL ALLOW FOR THE LEAST AMOUNT OF PIPE NEEDED TO SUPPLY THE QUARTER WITH WATER. THE DEPTH OF THE WELLS RANGES FROM 20 TO 100 FEET, AND IF THE WELL IS BOTTOMED IN THE TILL IT WILL PROVIDE A SOLID BASE FOR THE CASING AND PUMP. THE DIAMETER OF THE IRRIGATION WELLS IS AT LEAST 20 INCHES, AND CASING IS RUN THE ENTIRE LENGTH OF THE WELL. THE BOTTOM 20 OR 30 FEET OF THE CASING IS PERFORATED TO PROVIDE FOR ADEQUATE INTAKE OF THE WELL. TURBINE OR CENTRIFUGAL PUMPS, WHICH PRODUCE 500-1500 GALLONS PER MINUTE CAN SUPPLY THE AMOUNT OF WATER NEEDED. SPRINKLER SYSTEMS ARE SUCCESSFUL BECAUSE OF THE SANDY TEXTURE OF THE SOIL WHICH ALLOWS THE WATER TO PERCOLATE DOWNWARD QUITE RAPIDLY AND WOULD CAUSE EXCESSIVE WATER LOSS FROM DITCHES, AND BECAUSE OF THE FLATNESS OF THE GROUND SURFACE WHICH WOULD NOT PROVIDE ENOUGH SLOPE FOR DITCH FLOODING IN MOST PARTS OF THE AREA.

THE QUALITY OF THE WATER SHOULD BE CHECKED AT REGULAR INTERVALS BECAUSE OF THE INCREASE IN MINERALIZATION WHICH WILL ACCOMPANY THE RECIRCULATION OF THE WATER DURING THE IRRIGATING SEASON.

PROBLEMS ARISING FROM IRRIGATION:- WHEN LARGE AMOUNTS OF WATER ARE DRAWN FROM A RESERVOIR BY IRRIGATION, THE QUESTION OF ITS AFFECT ON NEIGHBORING WELLS IS ALWAYS RAISED. THESE WELLS CAN BE AFFECTED ONLY IF THE OVERALL WATER LEVEL OF THE RESERVOIR IS LOWERED OR IF THE NEIGHBORING WELL IS WITHIN THE INFLUENCE OF THE CONE OF DEPRESSION OF THE IRRIGATION WELL.

THE OVERALL WATER LEVEL OF THE RESERVOIR WILL BE MAINTAINED IF THE RECHARGE EQUALS OR EXCEEDS THE DISCHARGE. THIS CAN BE CALCULATED BY MEANS OF OBSERVATION WELLS AND FOR THIS PURPOSE, 15 SUCH WELLS WERE PLACED IN THE RESERVOIR DURING THE SUMMER OF 1956 AND READ AT REGULAR INTERVALS SINCE THAT TIME (TABLE 7). IN THE SHORT TIME THAT THESE RECORDS HAVE BEEN KEPT, THEY DO NOT SHOW A SIGNIFICANT LOWERING OF THE WATER TABLE.

EVEN IF THE OVERALL WATER LEVEL IS NOT LOWERED, THERE IS A LOCAL LOWERING OF THE WATER LEVEL NEAR ANY WELL WHICH IS BEING PUMPED, CALLED THE CONE OF DEPRESSION OR DRAWDOWN. THE ZONE OF INFLUENCE OF THE CONE OF DEPRESSION IS DEPENDENT ON THE RATE OF PUMPAGE AND THE PERMEABILITY OF THE MATERIAL SURROUNDING

THE WELL. IN EXTREMELY PERMEABLE MATERIAL, SUCH AS SAND AND GRAVEL, WATER PERCOLATES SO RAPIDLY TO THE WELL THAT LARGE VOLUMES CAN BE PUMPED WITH VERY LITTLE DRAWDOWN. THE CONE OF DEPRESSION, HOWEVER, CAN REACH 3 OR 4 HUNDRED FEET FROM THE WELL, IN SUCH MATERIAL, BUT IS VERY FLAT. THEREFORE, DOMESTIC WELLS WHICH ARE CLOSE ENOUGH TO IRRIGATION WELLS TO BE WITHIN THE INFLUENCE OF THE CONE OF DEPRESSION MAY SUFFER WATER DEPLETION DURING THE PUMPING SEASON. THIS IS ESPECIALLY TRUE IF THEY ARE IN THE VERY SHALLOW SANDS AND GRAVELS AT THE EDGE OF THE OUTWASH. THIS, HOWEVER, IS NOT A PERMANENT DIFFICULTY AS RECHARGE TAKES PLACE WHEN PUMPING IS STOPPED AND THERE ARE ONLY A VERY FEW WELLS LOCATED AT SUCH PLACES.

THE RESIDENTS WHO HAVE DOMESTIC WELLS LOCATED IN THE TILL SURROUNDING THE RESERVOIR HAVE ALSO SHOWN SOME CONCERN ABOUT THE POSSIBILITY THAT THEIR WATER SUPPLIES MAY BE LOWERED BY IRRIGATION. IT IS POSSIBLE THAT OVER A PERIOD OF MANY YEARS THE WATER TABLE IN THE TILLS COULD BE LOWERED SOMEWHAT BY SLOW SEEPAGE INTO THE OUTWASH RESERVOIR. THIS SEEPAGE WOULD BE VERY SLOW BECAUSE OF THE HIGH CLAY CONTENT (TABLE 8) OF THE TILLS WHICH MAKE THEM FAIRLY IMPERMEABLE. A RECORD OF THE WATER LEVEL, WHICH HAS BEEN KEPT BY THE STATE GEOLOGICAL SURVEY FOR THE PAST 20 YEARS, ON A WELL ON THE JOHN DAVIS FARM ALONG A SMALL STREAM WHICH FLOWS DIRECTLY INTO THE RESERFOIR (SEC. 29, T99N., R53W.), SHOWS NO APPRECIABLE DROP IN THE WATER LEVEL DURING THAT PERIOD (FIG. 6). MR. DAVIS REPORTS THAT HE HAS HAD TROUBLE OBTAINING WATER FROM THIS WELL IN THE LAST YEAR OR TWO AND THIS IS PROBABLY DUE TO SILTING IN OF THE WELL RATHER THAN TO WITHDRAWAL BY IRRIGATION WELLS AS THE DAVIS WELL IN 1947 WAS 12½ FEET DEEP (CADDES 1947, P 39) BUT IN THE SUMMER OF 1956 IT WAS ONLY 11 FEET DEEP. IT HAS ALWAYS BEEN DIFFICULT TO GET A PRODUCTIVE WELL FROM THE TILL IN THIS AREA BECAUSE THE SIOUX QUARTZITE IS SO CLOSE TO THE SURFACE THAT THERE ARE ONLY 50 OR 100 FEET OF "TIGHT" SEDIMENTS FROM WHICH WATER CAN BE DRAWN.

IF, IN THE FUTURE, IT IS DETERMINED FROM OBSERVATION WELL RECORDS THAT THE WATER LEVEL OF THE RESERVOIR IS DROPPING BELOW ITS NORMAL FLUCTUATION, STEPS SHOULD BE TAKEN TO LIMIT THE IRRIGATION UNTIL THE RECHARGE HAS AGAIN REPLENISHED THE WATER TO THE RESERVOIR. IF, HOWEVER, IT IS DETERMINED THAT THE WATER LEVEL OF THE RESERVOIR IS MAINTAINING ITSELF, IRRIGATION CAN, WITHOUT DETRIMENT TO THE WATER USERS, CONTINUE.

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FIGURES, TABLES,

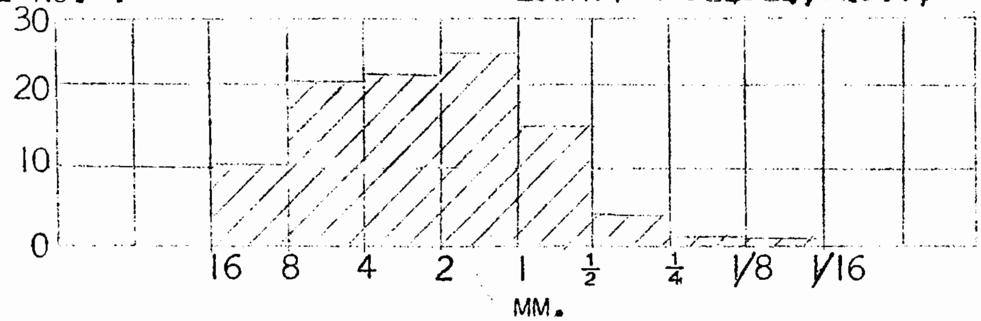
AND

STATISTICAL DATA

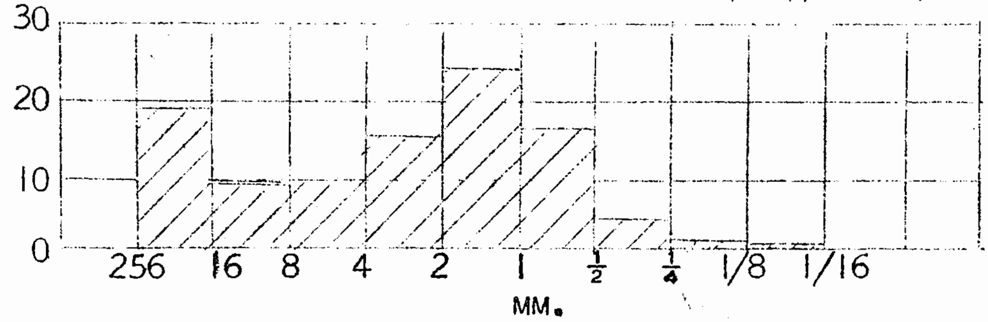
FIG. 2

HISTOGRAMS SHOWING GRAIN SIZE DISTRIBUTION OF GRAVEL

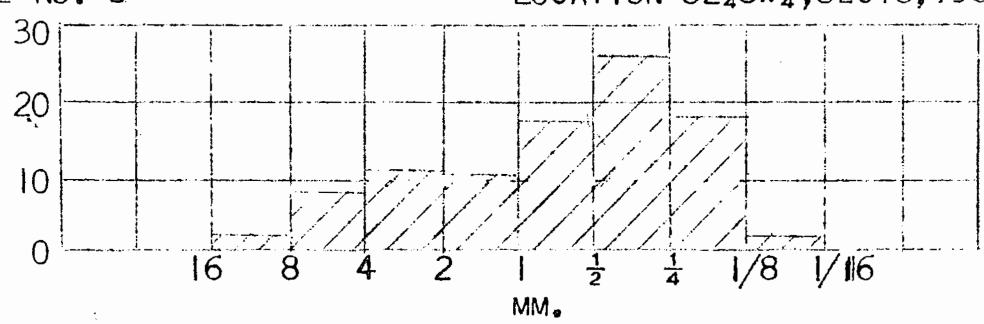
SAMPLE NO. 1 LOCATION SE¼SE¼, SEC 11, T99N, R53W.



SAMPLE NO. 2 LOCATION NW¼NW¼, SEC 25, T99N, R53W.



SAMPLE NO. 3 LOCATION SE¼SW¼, SEC 18, T98N, R53W.



SAMPLE NO. 4 LOCATION SW¼, SEC 25, T95N, R52W.

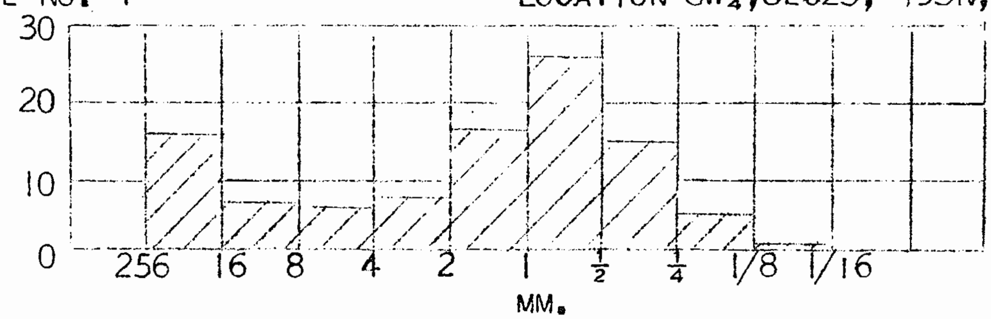
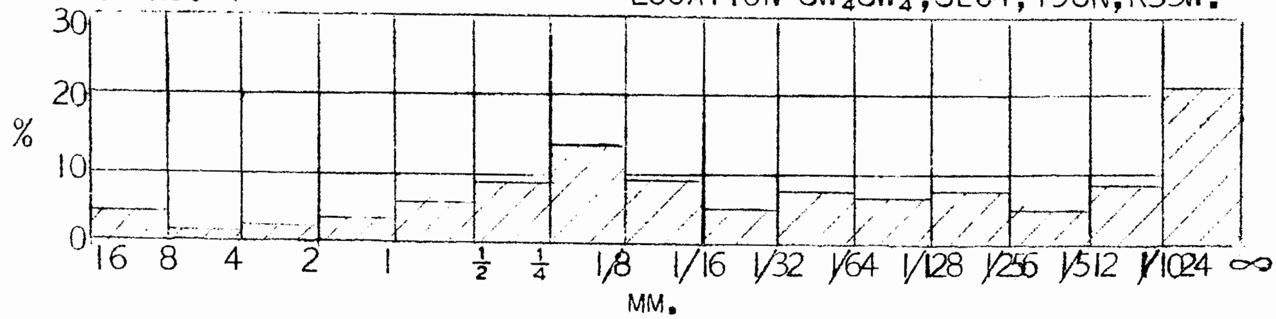


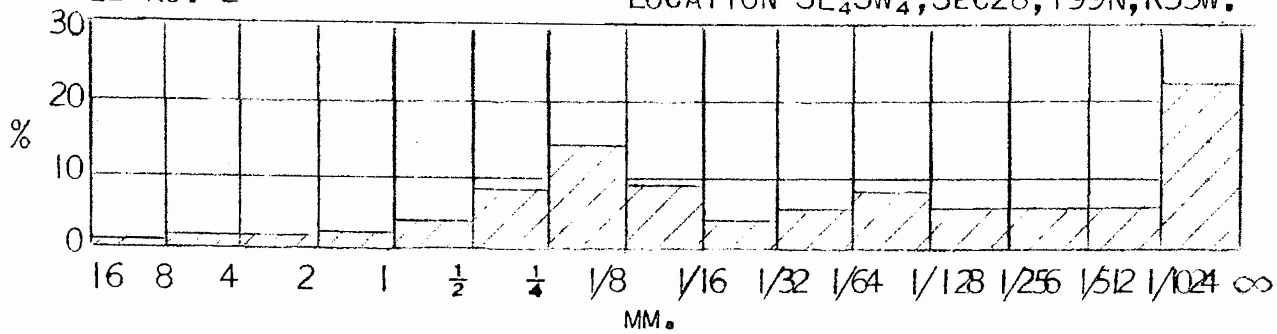
FIG. 3

HISTOGRAMS SHOWING GRAIN SIZE DISTRIBUTION OF TILLS

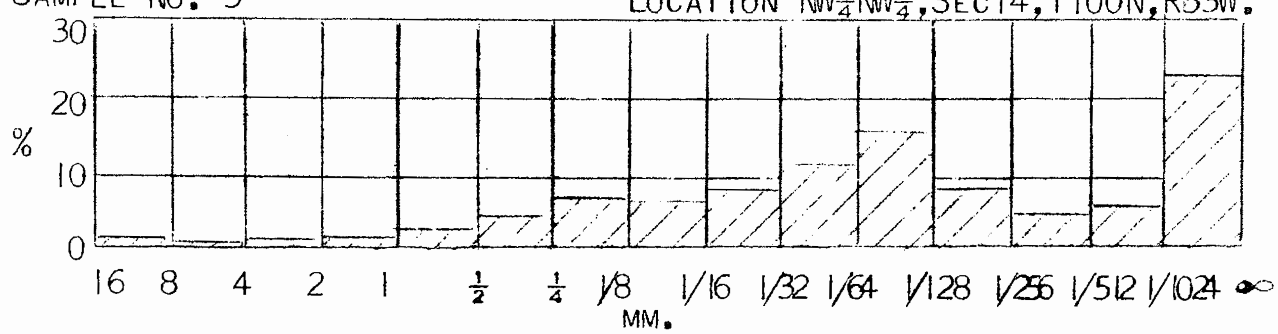
SAMPLE No. 1 LOCATION SW$\frac{1}{4}$SW$\frac{1}{4}$, SEC4, T98N, R53W.



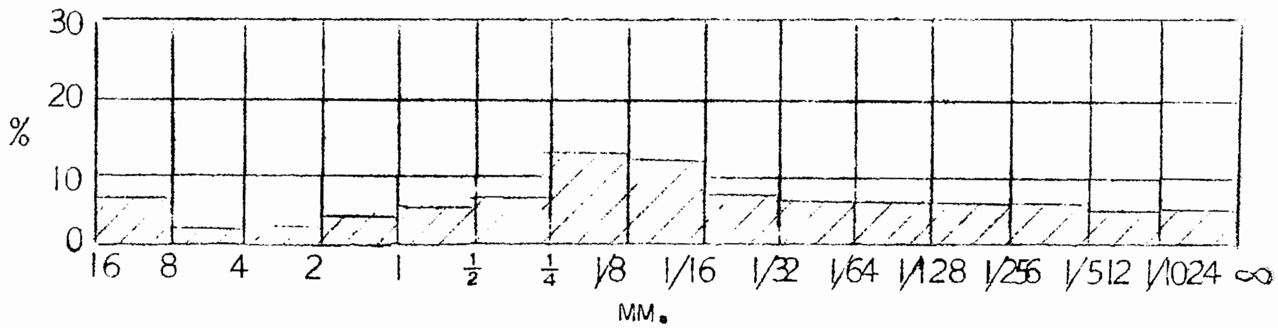
SAMPLE No. 2 LOCATION SE$\frac{1}{4}$SW$\frac{1}{4}$, SEC28, T99N, R53W.



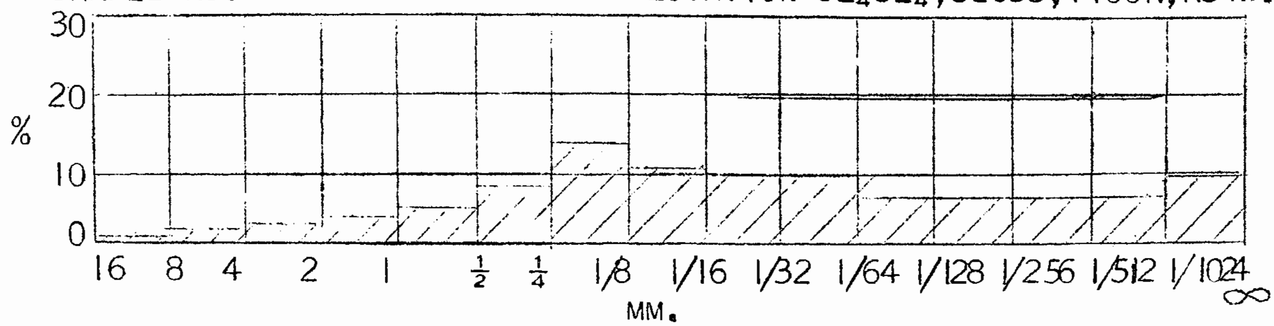
SAMPLE No. 3 LOCATION NW$\frac{1}{4}$NW$\frac{1}{4}$, SEC14, T100N, R53W.



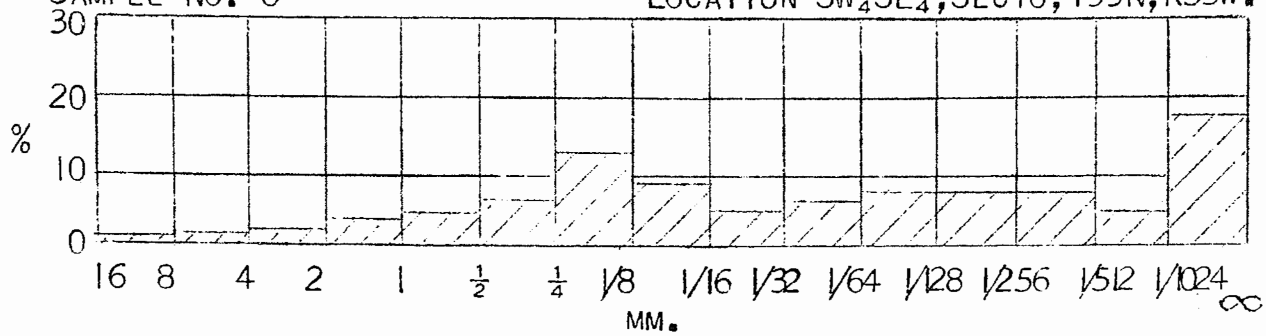
SAMPLE No. 4 LOCATION SE$\frac{1}{4}$SE$\frac{1}{4}$, SEC18, T100N, R53W.



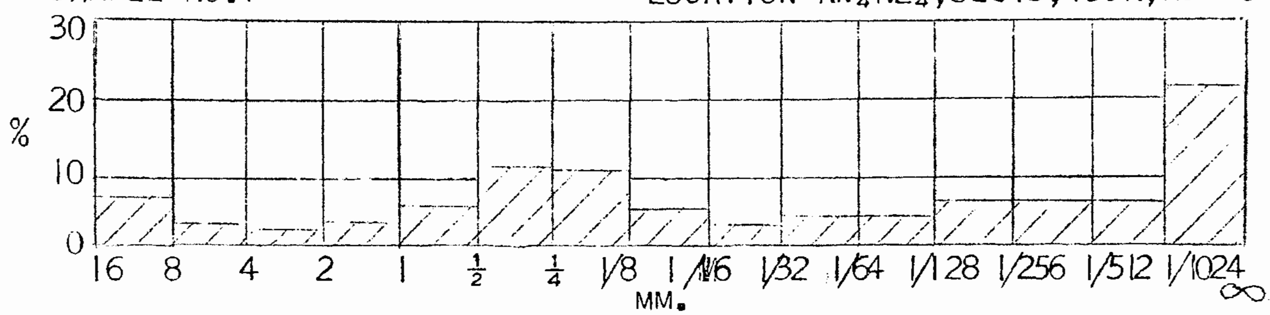
SAMPLE No. 5 — LOCATION SE¼SE¼, SEC 35, T100N, R54W.



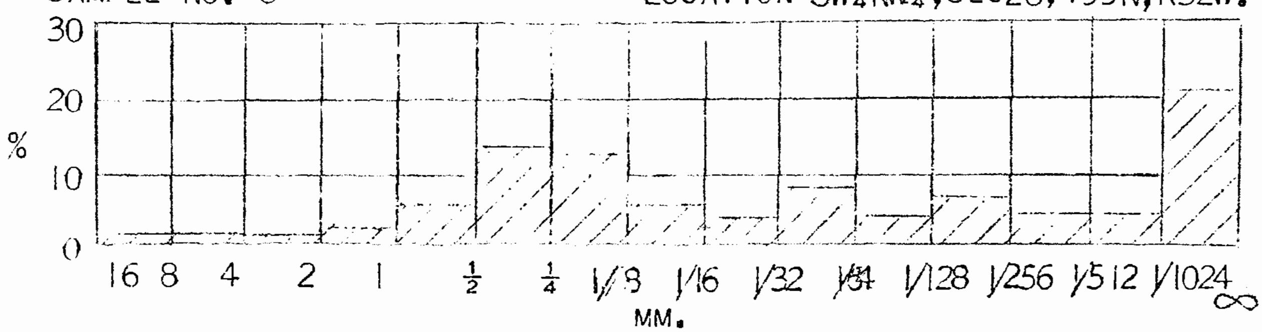
SAMPLE No. 6 — LOCATION SW¼SE¼, SEC 10, T99N, R53W.



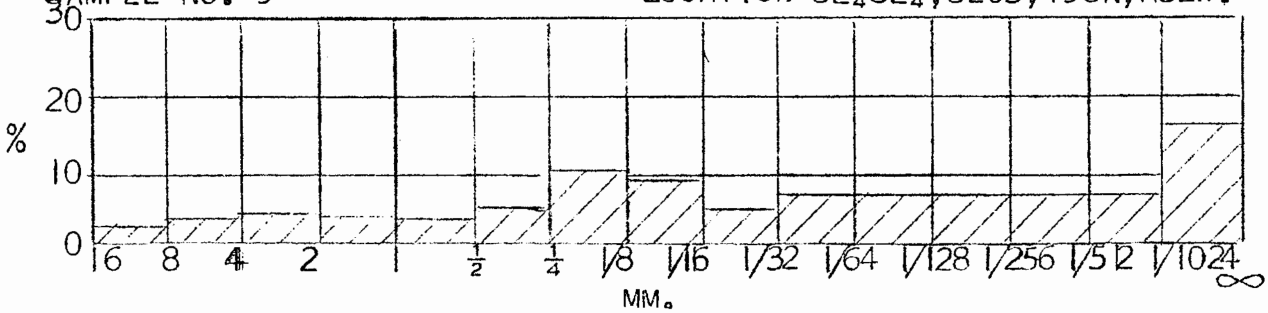
SAMPLE No. 7 — LOCATION NW¼NE¼, SEC 13, T99N, R53W.



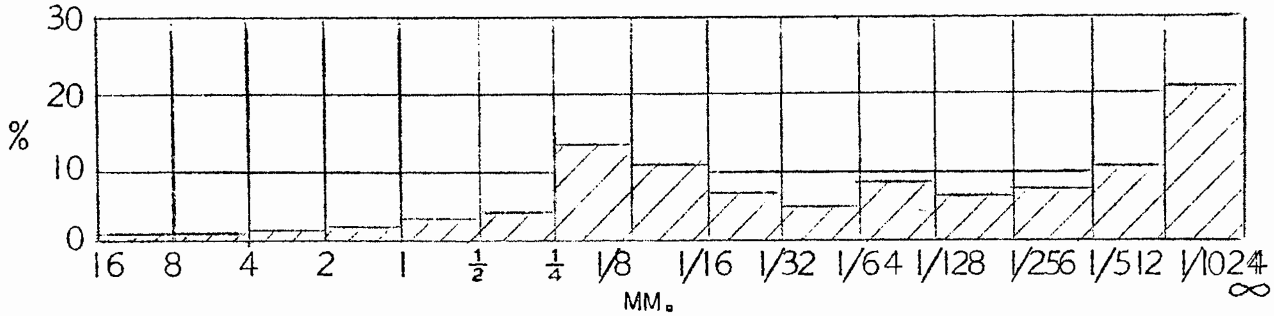
SAMPLE No. 8 — LOCATION SW¼NW¼, SEC 28, T99N, R52W.



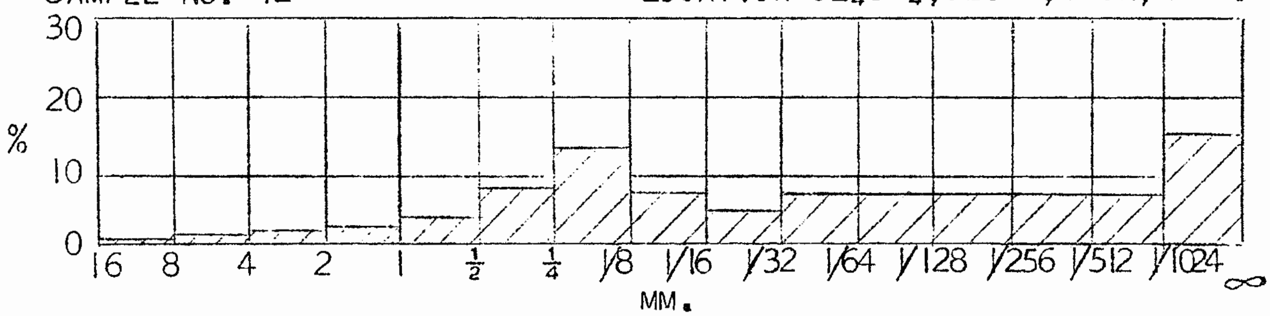
SAMPLE NO. 9 LOCATION SE¼SE¼, SEC5, T98N, R52W.



SAMPLE NO. 11 LOCATION SE¼SW¼, SEC23, T98N, R54W.



SAMPLE NO. 12 LOCATION SE¼SW¼, SEC34, T98N, R53W.



SAMPLE NO. 13 LOCATION SE¼SE¼, SEC9, T97N, R53W.

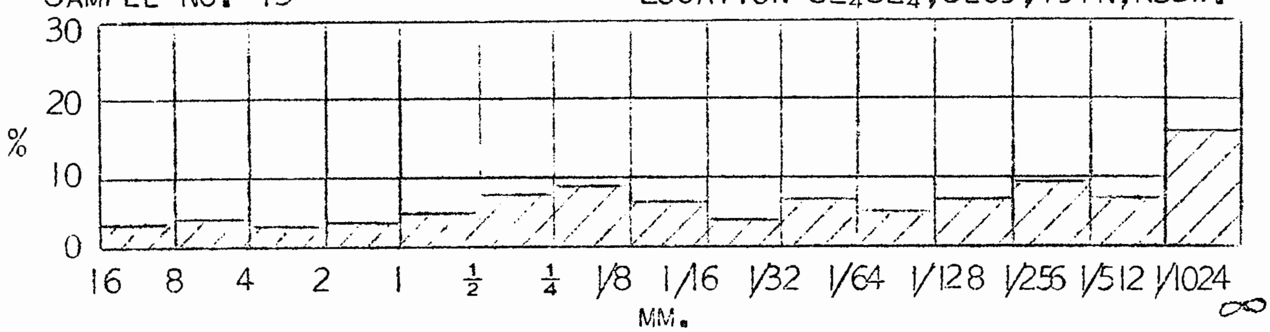


Fig. 4

Cumulative Curves Showing Grain-Size of the Same Sediments
Presented as Histograms in Figures 2-3.

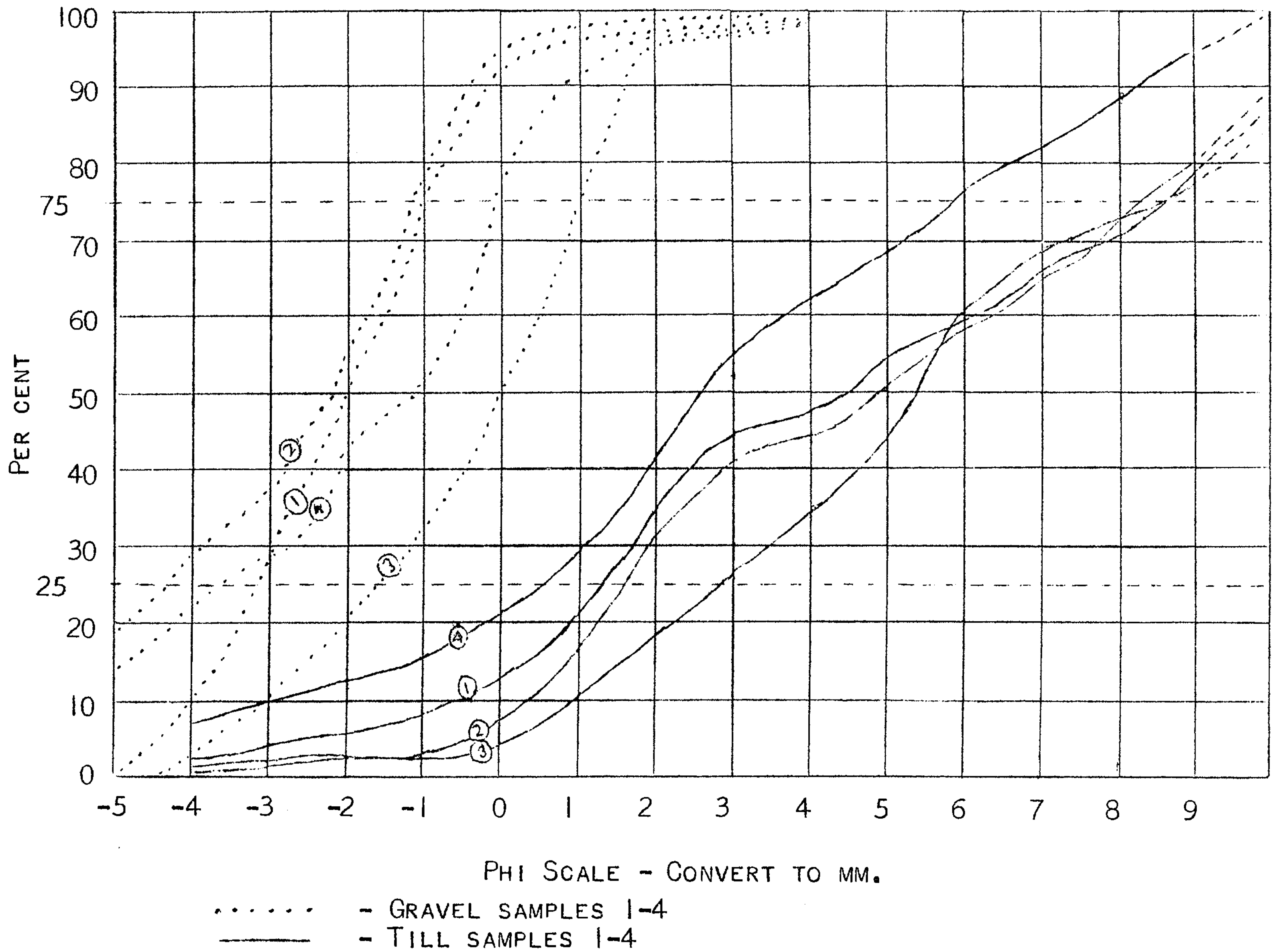
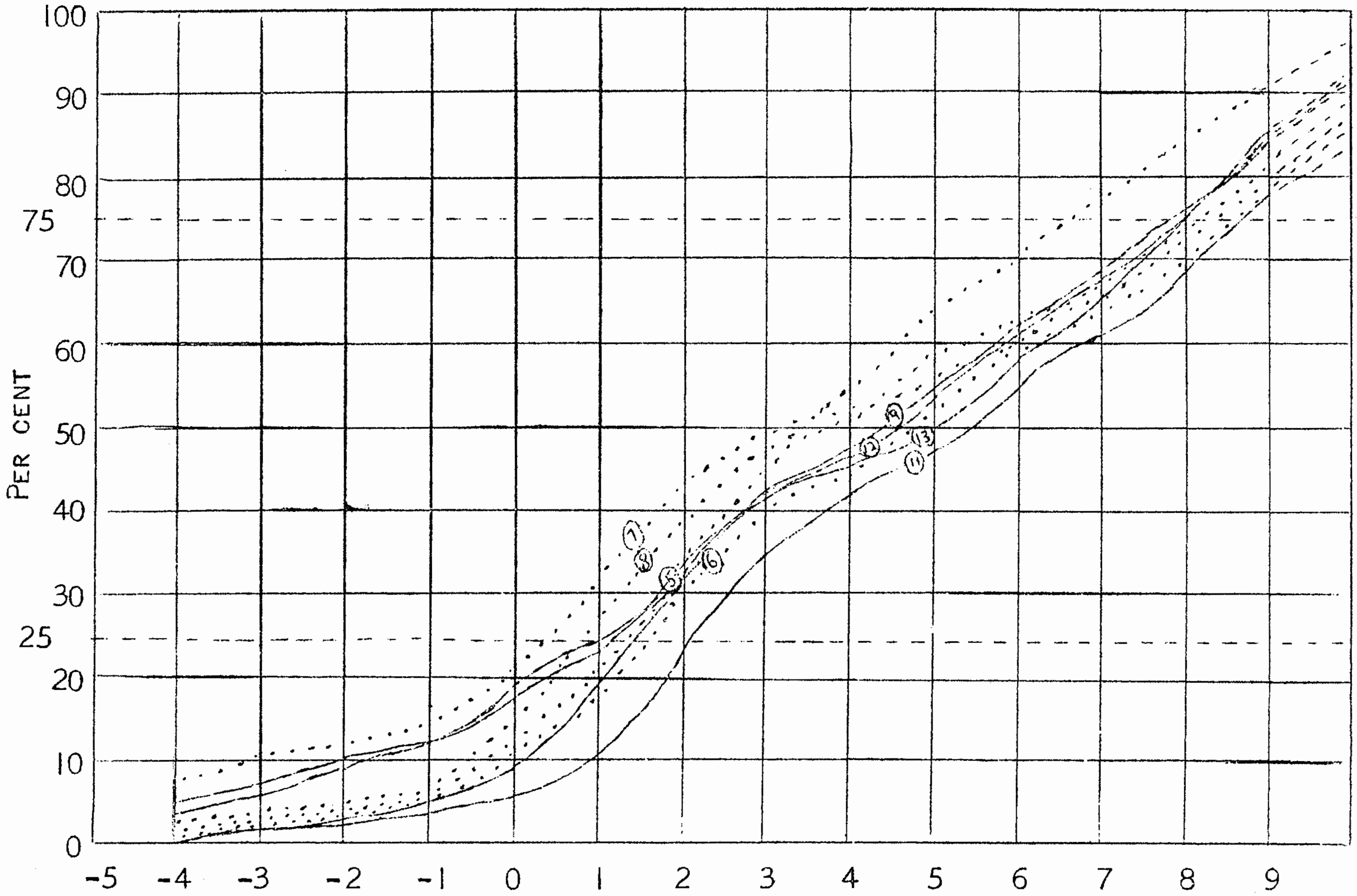


FIG. 5

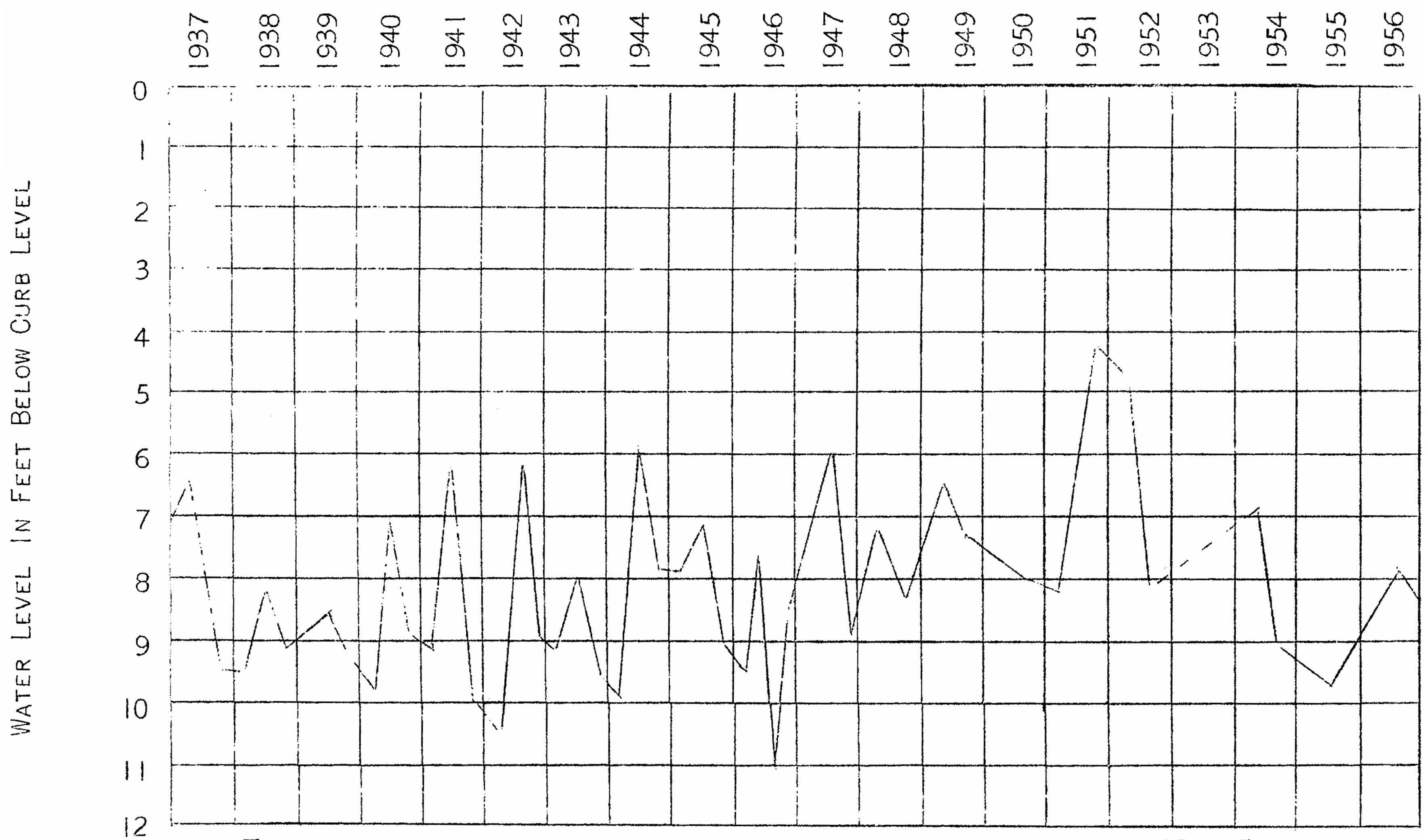
CUMULATIVE CURVES SHOWING GRAIN-SIZE OF THE SAME SEDIMENTS PRESENTED AS HISTOGRAMS IN FIGURE 3.



..... - TILL SAMPLES 5-8

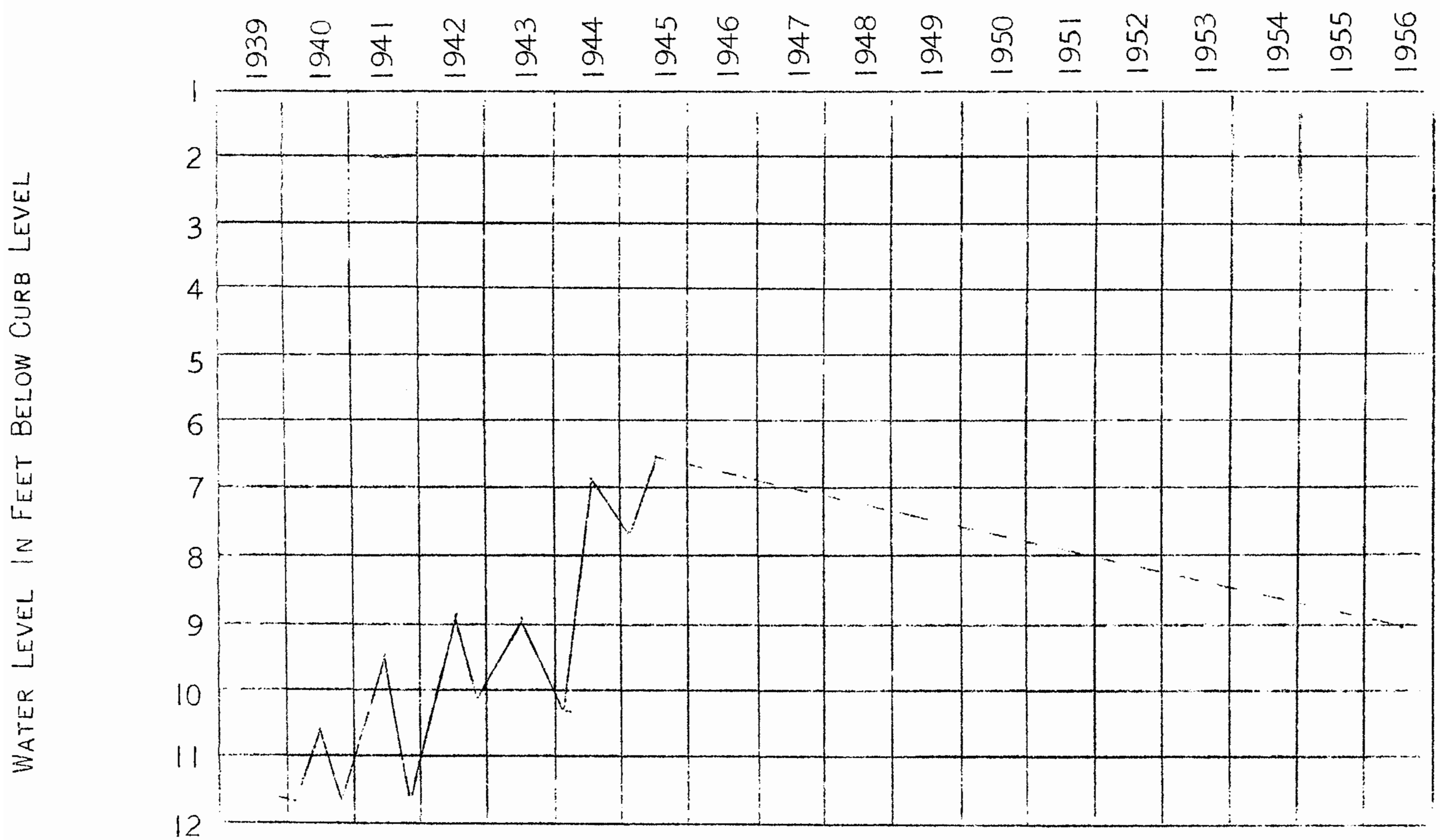
——— - TILL SAMPLES 9, 11, 12, 13

FIG. 6 - STATE GEOLOGICAL SURVEY OBSERVATION WELL NO. 22



THE ABOVE GRAPH SHOWS WATER LEVEL FLUCTUATIONS OF WELL NO. 22. THE WELL IS LOCATED IN THE $NE\frac{1}{4}, NE\frac{1}{4}$, SEC. 29, T99N., R53W., IN A CREEK BOTTOM. THIS WELL HAS A 42" CEMENT CASING AND IS 11' DEEP. DASHED LINE INDICATES LONG PERIOD WHEN NO READINGS WERE OBTAINED.

FIG. 7 - STATE GEOLOGICAL SURVEY OBSERVATION WELL NO. 42



THE ABOVE GRAPH SHOWS WATER LEVEL FLUCTUATIONS OF WELL NO. 42. THIS WELL IS LOCATED IN THE SE$\frac{1}{4}$,SE$\frac{1}{4}$, SEC. 26, T98N., R53W., ON THE OUTWASH RESERVOIR. THE WELL WAS PLUGGED IN 1945 AND NO READINGS COULD BE MADE AFTER THAT DATE. THE READING SHOWN IN 1956 WAS TAKEN FROM AN IRRIGATION WELL LOCATED ABOUT 50 YARDS WEST OF THE OLD WELL.

TABLE I

ANNUAL AND MONTHLY AVERAGE PRECIPITATIONS
AND MEAN TEMPERATURES
1938-1955

YEAR	PRECIPITATION (INCHES) MARION	CENTERVILLE	AVERAGE	AVERAGE TEMPERATURE
1938	19.97	25.24	22.60	49.2
1939	17.68	14.80	16.24	50.0
1940	27.46	27.23	27.34	46.8
1941	19.12	20.66	19.89	49.5
1942	31.92	28.49	30.20	47.9
1943	23.62	23.68	28.65	47.8
1944	39.74	42.53	41.13	48.1
1945	22.12	22.99	22.55	47.1
1946	29.99	24.67	27.33	49.4
1947	22.20	24.28	23.24	47.8
1948	27.55	21.40	24.47	47.2
1949	18.03	22.80	20.41	47.9
1950	22.78	No record	22.78	44.0
1951	30.33	33.63	31.98	44.2
1952	18.31	18.81	18.56	46.9
1953	25.47	29.00	27.23	49.1
1954	25.41	30.31	27.81	49.1
1955	18.19	15.04	16.61	48.7

MONTHLY AVERAGE OF PRECIPITATION (INCHES) 1938-1955

January	0.47	May	3.27	September	2.38
February	1.05	June	4.89	October	1.55
March	1.53	July	2.85	November	0.87
April	2.18	August	2.90	December	0.54

TABLE 4 COMPOSITION OF THE GLACIAL TILLS (PERCENT)
(FOR LOCATIONS SEE TABLE 5)

SAMPLE / ROCK TYPE	1	2	3	4	5	6	7	8	9	10	11	12	13
CHALK	8.0	25.1	3.1	9.9	0.3	3.6	58.0	27.8	77.0	38.4	1.4	23.0	41.7
SHALE	13.7	12.6	11.9	9.7	24.2	13.7	2.3	7.7	9.1	12.0	29.4	6.2	9.6
RED-PINK GRANITE	2.3	2.4	4.8	4.4	4.8	2.5	2.1	2.5	1.1	2.4	3.4	3.4	3.5
LITE COLORED GRANITE	9.0	6.7	18.6	9.7	9.3	9.1	5.5	6.7	2.3	9.8	10.4	12.6	13.0
DIORITE	2.3	0.2	0.3	0.2	0.1	0.3	0.0	0.1	0.0	0.0	0.0	0.5	0.0
GABBRO	0.8	0.5	1.1	0.7	0.8	0.6	0.6	1.8	0.1	0.2	0.8	0.2	0.0
GREENSTONE	0.5	2.6	2.5	1.3	1.5	2.7	1.9	3.3	0.7	4.4	3.4	3.6	2.6
FINE GRAINED IGNEOUS	1.0	1.4	4.5	1.2	2.6	1.7	1.5	1.2	0.1	0.9	0.6	0.3	0.5
MISC. IGNEOUS	0.3	1.0	2.3	1.9	1.3	1.1	1.6	0.8	0.1	0.7	0.0	0.5	1.7
SCHIST	0.3	0.0	0.3	0.5	0.1	0.9	0.1	0.5	0.0	0.0	0.0	0.3	0.1
QUARTZITE	0.8	0.3	0.6	0.3	0.6	0.2	0.0	0.0	0.0	0.4	0.0	0.0	0.0
LIMESTONE	20.4	30.3	23.4	34.6	24.0	21.5	11.9	19.3	2.6	7.4	14.6	19.2	7.3
DOLOMITE	13.2	6.2	13.8	19.8	23.1	22.5	8.6	13.9	1.1	8.8	24.5	16.6	13.2
CHERT	1.3	0.5	1.1	0.3	0.6	0.4	0.2	1.1	0.0	0.2	0.3	1.1	0.6
HARD SHALE	0.8	1.2	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
SANDSTONE	3.4	0.7	2.3	1.1	1.3	1.4	0.3	3.7	0.0	1.1	0.8	1.1	0.6
LIMONITIC CONC.	6.4	6.1	8.4	3.8	5.4	13.0	5.4	9.2	5.6	13.1	10.4	8.5	5.0
FOSSILS	0.5	0.0	0.8	0.2	0.0	0.0	0.0	0.3	0.1	0.2	0.0	2.8	0.5
CALICHE	15.0	2.1	0.0	0.3	0.0	4.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SIOUX QUARTZITE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
TOTAL	100.0	99.9	99.8	100.0	100.0	99.8	100.0	100.0	99.9	100.0	100.0	99.9	100.0

TABLE 5 PEBBLE COUNTS, MEDIAN DIAMETERS, SORTING COEFFICIENTS OF TILL & GRAVELS

Till Sample No.	Location	Pebbles Foreign to So. Dak.			Median Diameter (mm)	Sorting Coefficient
		Limestone	Granite	Greenstone		
1	SW$\frac{1}{4}$ NE$\frac{1}{4}$, Sec. 4, T98N., R53W.	77%	21%	1%	0.42	14.5
2	SE$\frac{1}{4}$ SW$\frac{1}{4}$, Sec. 28, T99N., R53W.	76%	18%	5%	0.32	10.3
3	NW$\frac{1}{4}$ NW$\frac{1}{4}$, Sec. 14, T100N., R53W.	60%	36%	4%	0.12	7.7
4	SE$\frac{1}{4}$ SE$\frac{1}{4}$, Sec. 18, T100N., R53W.	78%	20%	2%	0.65	8.1
5	SE$\frac{1}{4}$ SE$\frac{1}{4}$, Sec. 35, T100N., R54W.	76%	21%	3%	0.39	6.3
6	SW$\frac{1}{4}$ SE$\frac{1}{4}$, Sec. 10, T99N., R53W.	77%	18%	5%	0.31	10.2
7	NW$\frac{1}{4}$ NE$\frac{1}{4}$, Sec. 13, T99N., R53W.	69%	24%	7%	0.78	16.1
8	SW$\frac{1}{4}$ NW$\frac{1}{4}$, Sec. 28, T99N., R52W.	73%	20%	7%	0.53	13.2
9	SE$\frac{1}{4}$ SE$\frac{1}{4}$, Sec. 5, T98N., R52W.	47%	44%	9%	0.42	10.3
10	SE$\frac{1}{4}$ SW$\frac{1}{4}$, Sec. 31, T98N., R51W.	49%	37%	13%	----	----
11	SE$\frac{1}{4}$ SW$\frac{1}{4}$, Sec. 23, T98N., R54W.	69%	24%	7%	0.23	10.7
12	SE$\frac{1}{4}$ SW$\frac{1}{4}$, Sec. 34, T98N., R53W.	65%	29%	6%	0.32	9.0
13	SE$\frac{1}{4}$ SE$\frac{1}{4}$, Sec. 9, T97N., R52W.	51%	41%	7%	0.48	12.6
Gravel Sample No.						
1	SE$\frac{1}{4}$ SW$\frac{1}{4}$, Sec. 11, T99N., R53W.	67%	25%	8%	4.14	2.35
2	NW$\frac{1}{4}$ NW$\frac{1}{4}$, Sec. 25, T99N., R53W.	60%	30%	10%	4.43	3.11
3	SE$\frac{1}{4}$ SW$\frac{1}{4}$, Sec. 18, T98N., R53W.	62%	29%	8%	1.00	2.55
4	SW$\frac{1}{4}$, Sec. 25, T95N., R52W.	53%	39%	8%	2.14	3.52

TABLE 6 WATER ANALYSIS

Sample No.	1	2	3	4	5
Owner	Claude Sherard	Harm Hagena	Bones Ranch	Roy Flyger	Weldon Wirt
Location	Sec13, T98N, R53W.	Sec29, T98N, R52W.	Sec25, T99N, R53W.	Sec5, T98N, R53W.	Sec28, T99N, R53W
Class of Water	I	I	II	II	III
Character of Sed.	Outwash	Outwash	Outwash	Outwash	Till
		Parts	Per	Million	
Total Solids	594	425	1106	1309	1692
Chlorides (Cl)	1	None	1	None	19
Sulfates (SO_4)	193	131	506	616	835
Silica (SiO_2)	25	25	36	34	17
Calcium (Ca)	100	72	180	206	268
Magnesium (Mg)	43	33	75	86	83
Alkalinity ($CaCO_3$)	13	10	6	8	8
Methyl Orange	118	122	90	93	95
Hardness ($CaCO_3$)	427	316	758	868	101[illegible]
Iron	Trace	None	1.5	Trace	27
Manganese (Mn)	Trace	None	1.4	1	.4
Fluoride (Fl)	None	None	None	None	None
Sodium (Na)	20	6	26	51	109

TABLE 7

OBSERVATION WELL READINGS

Well	Location	Elev. Above Sea Level	Depth to Water From Top of Ground-1956			
			August	September	October	November
A	NE$\frac{1}{4}$, Sec.35, T99N., R53W.,	1293.9 feet	15.5 feet	15.7 feet	15.8 feet	15.8 feet
B	NW$\frac{1}{4}$, Sec. 4, T98N., R53W.,	1308.3 feet	24.7 feet	24.4 feet	24.6 feet	Not read
C	NW$\frac{1}{4}$, Sec. 4, T98N., R53W.,	1308.1 feet	24.5 feet	24.1 feet	Not read	Not read
D	NW$\frac{1}{4}$, Sec. 4, T98N., R53W.,	1307.8 feet	24.4 feet	24.3 feet	Not read	Not read
E	NW$\frac{1}{4}$, Sec. 4, T98N., R53W.,	1307.6 feet	24.7 feet	24.1 feet	23.7 feet	23.5 feet
F	SW$\frac{1}{4}$, Sec. 5, T98N., R53W.,	1301.7 feet	12.3 feet	12.5 feet	12.7 feet	13.0 feet
G	SW$\frac{1}{4}$, Sec. 4, T98N., R53W.,	1285.8 feet	6.6 feet	6.3 feet	6.7 feet	5.7 feet
H	NW$\frac{1}{4}$, Sec. 9, T98N., R53W.,	1284.2 feet	6.0 feet	6.2 feet	6.1 feet	5.7 feet
I	SW$\frac{1}{4}$, Sec. 3, T98N., R53W.,	1278.8 feet	5.4 feet	5.7 feet	5.9 feet	5.8 feet
J	SW$\frac{1}{4}$, Sec. 1, T98N., R53W.,	1284.6 feet	14.5 feet	14.7 feet	14.8 feet	14.7 feet
K	NW$\frac{1}{4}$, Sec.16, T98N., R53W.,	1267.5 feet	6.9 feet	8.1 feet	9.1 feet	8.7 feet
L	NE$\frac{1}{4}$, Sec.16, T98N., R53W.,	1273.4 feet	5.6 feet	5.8 feet	6.0 feet	5.9 feet
M	NE$\frac{1}{4}$, Sec.14, T98N., R53W.,	1276.0 feet	14.6 feet	14.9 feet	14.9 feet	14.7 feet
N	NE$\frac{1}{4}$, Sec.13, T98N., R53W.,	1275.1 feet	16.3 feet	16.5 feet	16.4 feet	16.3 feet
O	NE$\frac{1}{4}$, Sec.26, T98N., R53W.,	1260.3 feet	12.6 feet	12.9 feet	13.1 feet	12.7 feet

TABLE 8 SIZE RANGE OF TILLS IN MM.

Sample No.	Screen Sizes										Pipette Sizes						Percentage		
	32	16	8	4	2	1	1/2	1/4	1/8	1/16	1/32	1/64	1/128	1/256	1/512	1/1024	Sand & Gravel	Silt	Clay
1		3.9	1.0	1.4	2.7	4.5	8.5	13.2	8.4	4.0	6.7	5.4	6.7	4.0	8.0	21.5	47.6	22.8	29.5
2		0.4	1.1	1.3	1.8	3.7	8.7	14.2	9.1	3.9	6.5	8.5	6.5	6.5	6.5	22.0	44.2	28.0	28.5
3		1.4	0.4	0.7	1.1	2.3	4.8	7.9	7.0	8.3	11.0	15.1	8.3	4.1	5.5	22.0	33.9	38.5	27.5
4		7.7	2.5	2.7	3.9	4.9	7.5	13.0	12.0	7.8	6.7	6.7	6.7	6.7	5.6	5.6	62.0	26.8	11.2
5		0.7	1.6	2.2	3.4	4.9	8.2	13.2	10.1	9.8	9.8	6.6	6.6	6.6	6.6	9.8	54.1	29.6	16.4
6		1.0	1.2	2.0	3.0	4.2	6.8	12.8	9.2	4.8	6.1	8.5	8.5	8.5	4.8	18.3	45.0	31.6	23.1
7		7.5	2.9	2.1	2.8	6.3	11.6	11.0	5.4	3.0	4.0	4.0	6.0	6.0	6.0	21.4	52.6	20.0	27.4
8		1.7	1.7	1.5	2.4	6.8	13.7	12.5	6.3	3.5	8.2	4.6	6.9	4.6	4.6	21.0	50.1	24.3	25.6
9		2.3	3.2	4.1	3.9	3.6	5.6	10.9	8.9	4.8	7.2	7.2	7.2	7.2	7.2	16.7	47.3	28.8	23.9
10		0.6	2.4	1.5	2.3	6.4	4.3	7.8	3.3	---	---	---	---	---	---	----	----	----	---
11		0.9	0.8	1.0	1.3	2.0	4.6	13.8	10.9	6.8	5.1	8.5	6.2	7.5	10.2	20.5	42.1	27.3	30.7
12		0.5	1.0	1.4	2.5	4.5	8.8	13.6	8.0	5.2	7.8	7.8	7.8	7.8	7.8	15.5	45.5	31.2	23.3
13		3.6	3.8	2.5	3.1	4.6	7.1	9.4	6.7	3.3	7.6	5.6	8.2	9.9	8.2	16.4	44.1	31.3	24.6

TABLE 9

WATER LEVELS AND PRODUCTION
HURLEY CITY WELL

Date		Depth to Water	Gallons Water Used
November	1955	13 feet 2 inches	720,600
December	1955	12 feet 11 inches	595,400
January	1956	12 feet 4 inches	461,000
February	1956	12 feet 4 inches	491,000
March	1956	12 feet 4 inches	536,000
April	1956	12 feet 0 inches	864,000
May	1956	11 feet 11 inches	1,396,300
June	1956	11 feet 11 inches	2,901,800
July	1956	12 feet 2 inches	2,578,100
August	1956	12 feet 7 inches	4,285,300
September	1956	13 feet 8 inches	5,517,600
October	1956	13 feet 2 inches	1,976,000
Total			22,323,100

IRRIGATION WELL RECORDS

Owner or Tenant	No.	Location ¼	Sec	T	R	Type Well	Well Depth	Well Dia.	Type of Casing	Height Above Sea Lev.	Geologic Source	Character of Material	Use of Water	Date Drill-ed	Depth to Water
Coston, R	32	SE	14	99	53	Bored	44'	20"	Steel	1305'	Outwash	Sand, grav.	Irr.	1956	14'
Coston, R	33	NW	23	99	53	Bored	41'	20"	Steel	1305'	Outwash	Sand, grav.	Irr.	1956	12'
Keeler, S	12	SE	26	99	53	Bored	24'	36"	Concrete	1291'	Outwash	Sand, grav.	Irr.	1954	11'
Larson, E	6	NE	34	99	53	Bored	34'	42"	Concrete	1290'	Outwash	Sand, grav.	Irr.	1955	14'
Stoddard	13	SE	35	99	53	Bored	34'	20"	Steel	1291'	Outwash	Sand, grav.	Irr.	1956	16'
Bones	27	NE	35	99	53	Bored	41'	20"	Steel	1299'	Outwash	Sand, grav.	Irr.	1956	17'
Bones	23	NE	35	99	53	Bored	30'	20"	Steel	1285'	Outwash	Sand, grav.	Irr.	1956	5'
Stoddard	14	SW	36	99	53	Bored	28'	42"	Concrete	1283'	Outwash	Sand, grav.	Irr.	1955	8'
Coston, R	34	NW	36	99	53	Bored	44'	20"	Steel	1290'	Outwash	Sand, grav.	Irr.	1956	13'
Stoddard	15	SW	31	99	53	Bored	32'	20"	Steel		Outwash	Sand, grav.	Irr.	1956	14'
Nyhouse	24	SW	1	98	53	Bored	30'	42"	Tile	1281'	Outwash	Sand, grav.	Irr.	1955	10'
Stoddard	16	NW	1	98	53	Bored	39'	20"	Steel	1281'	Outwash	Sand, grav.	Irr.	1956	10'
Stoddard	17	NE	1	98	53	Bored	45'	20"	Steel		Outwash	Sand, grav.	Irr.	1956	9'
Rundell	5	NE	3	98	53	Bored	53'	20"	Steel		Outwash	Sand, grav.	Irr.	1956	16'
Flyger, R	1	NW	4	98	53	Bored	93'	20"	Steel	1306'	Outwash	Sand, grav.	Irr.	1956	23'
Flyger, R	2	SW	4	98	53	Bored	53'	20"	Steel	1297'	Outwash	Sand, grav.	Irr.	1956	14'
Flyger, R	3	SE	5	98	53	Bored	44'	42"	Steel	1293'	Outwash	Sand, grav.	Irr.	1955	9'
Sherard	9	NE	8	98	53	Bored	57'	20"	Steel	1286'	Outwash	Sand, grav.	Irr.	1956	7'
Flyger, R	4	NE	9	98	53	Bored	70'	20"	Steel	1285'	Outwash	Sand, grav.	Irr.	1956	5'
Eiden, J	21	NE	10	98	53	Bored	30'	42"	Concrete	1281'	Outwash	Sand, grav.	Irr.	1955	15'
Bones	26	SE	11	98	53	Bored	50'	20"	Steel	1273'	Outwash	Sand, grav.	Irr.	1956	12'
Novak, H	22	NW	11	98	53	Bored	49'	20"	Steel	1272'	Outwash	Sand, grav.	Irr.	1956	9'
Reiners	7	NE	11	98	53	Bored	52'	20"	Steel	1277'	Outwash	Sand, grav.	Irr.	1956	14'
Flyger, M	20	NE	12	98	53	Bored	37'	20"	Steel	1276'	Outwash	Sand, grav.	Irr.	1956	12'

IRRIGATION WELL RECORDS

Owner or Tenant	No.	Location ¼	Sec	T	R	Type Well	Well Depth	Well Dia.	Type of Casing	Height Above Sea Lev.	Geologic Source	Character of Material	Use of Water	Date Drill-ed	Depth to Water
Sherard	8	NE	13	98	53	Bored	44'	20"	Steel	1264'	Outwash	Sand, grav.	Irr.	1954	14'
Bones	25	NE	14	98	53	Bored	55'?	20"	Steel	1272'	Outwash	Sand, grav.	Irr.	1956	17'
Eckhoff	30	NW	14	98	53	Bored	30'	18"	Steel	1272'	Outwash	Sand, grav.	Irr.	1956	14'
Flyger, M	19	SE	16	98	53	Bored	45'	20"	Steel	1272'	Outwash	Sand, grav.	Irr.	1956	3'
Steward	29	SE	23	98	53	Bored	26'	42"	Steel	1255'	Outwash	Sand, grav.	Irr.	1955	3'
Gocken, D	23	NW	23	98	53	Bored	37'	20"	Steel	1264'	Outwash	Sand, grav.	Irr.	1956	12'
Sherard	11	SE	25	98	53	Bored	38'	42"	Concrete	1251'	Outwash	Sand, grav.	Irr.	1955	8'
Flyger, C	31	SE	26	98	53	Bored	46'	20"	Steel	1259'	Outwash	Sand, grav.	Irr.	1956	9'
Sherard	10	NW	36	98	53	Bored	28'	42"	Concrete	1247'	Outwash	Sand, grav.	Irr.	1955	5'
Hagena, H	18	SE	20	98	52	Bored	53'	20"	Steel	1261'	Outwash	Sand, grav.	Irr.	1956	14'
Hagena, G		SW	29	98	52	Pumps	from abandoned gravel pit				Outwash	Sand, grav.	Irr.	1952	5'
Hanson, W	41	SE	27	96	52	Bored	39'	20"	Steel		Outwash	Sand, grav.	Irr.	1956	12'
Hanson, W	40	SW	27	96	52	Bored	42'	20"	Steel		Outwash	Sand, grav.	Irr.	1956	12'
Jones, L	37	SW	33	96	52	Bored	48'	20"	Steel		Outwash	Sand, grav.	Irr.	1956	10'
Knutson	39	NW	3	95	52	Bored	39'	20"	Steel		Outwash	Sand, grav.	Irr.	1956	8'
Hanson, W	42	SE	3	95	52	Bored	50'	20"	Steel		Outwash	Sand, grav.	Irr.	1956	15'
Knutson	38	NE	5	95	52	Bored	49'	20"	Steel		Outwash	Sand, grav.	Irr.	1956	?
Hunter, D	36	NW	14	95	52	Bored	41'	20"	Steel		Outwash	Sand, grav.	Irr.	1956	17'
Hunter, D	35	SW	14	95	52	Bored	48'	20"	Steel		Outwash	Sand, grav.	Irr.	1956	14'

DOMESTIC WELL RECORDS

Owner or Tenant	No.	Location ¼	Sec	T	R	Type Well	Well Depth	Well Dia.	Type of Casing	Height Above Sea Lev.	Geologic Source	Character of Material	Use of Water	Date Drill-ed	Depth to Water
Matthews, R		SW	8	99	53	Dug	22'	20"	Tile		Outwash	Sand, grav.	Stock	1920	?
Schaefer, C		SW	10	99	53	Dug	12'	36"	Cement		Outwash	Fine sand	Stock	1928?	6'
Kasten, G		NW	13	99	53	Bored	120'	6"	Steel		Drift	Till	Stock	1925	?

DOMESTIC WELL RECORDS

Owner or Tenant	Location				Type Well	Well Depth	Well Dia.	Type of Casing	Height Above Sea Lev.	Geologic Source	Character of Material	Use of Water	Date Drilled	Depth to Water
	1/4	Sec	T	R										
Blanchard, C	NE	14	99	53	Drove	69'	6"	Steel		Drift	Sand	House	?	45'
Mammenga, A	SE	15	99	53	Dug	21'	20"	Cement		Outwash	Sand, Grav	Stock	?	17'
Koller, A	SW	15	99	53	Bored	49'	4"	Steel		Drift	Till	House	1900?	35'
Dice, C	SE	19	99	53	Drove	55'	1"	Steel		Alluvium	Sand	House	?	?
Eichel, W	SE	21	99	53	Bored	35'	1"	Steel		Drift	Till	House	1931?	?
Johnson, D	NW	21	99	53	Bored	60'	6"	Steel		Drift	Sand	House	?	53'
Dorst, B	NE	21	99	53	Bored	50'	4"	Steel		Drift	Till	House	?	40'
Grudt, O	NE	22	99	53	Bored	22'	72"	Steel		Outwash	Sand, Grav	Stock	?	12'
Scott, F	NW	22	99	53	Bored	65'	2"	Steel		Drift	Till	Stock	1932	53'
Scott, F	NW	22	99	53	Bored	35'	6"	Steel		Drift	Till	House	1900	32'
Melzer, H	SW	23	99	53	Drove	30'	6"	Steel		Outwash	Sand, Grav	House	?	?
Costen, R	NE	23	99	53	Drove	17'	1"	Steel		Outwash	Sand, Grav	House	1950	12'
Zangeer, C	SW	24	99	53	Drove	32'	1"	Steel		Outwash	Sand, Grav	House	1930?	10'
DeNeui, O	NE	24	99	53	Bored	42'	36"	Tile		Outwash	Sand	Stock	1955	?
Hanson, R	SW	26	99	53	Drove	20'	1"	Steel		Outwash	Sand, Grav	Stock	1941	12'
Simonson, H	SE	27	99	53	Bored	40'	8"	Steel		Outwash	Sand, Grav	House	?	20'?
Simonson, H	SE	27	99	53	Bored	24'	8"	Concrete		Outwash	Sand, Grav	Stock	1949	12'
Finn, L	NE	27	99	53	Dug	36'	48"	Wood		Outwash	Sand, Grav	Stock	1916	33'
Wirt, W	SW	28	99	53	Bored	185'	6"	Steel		Sioux Fm	Quartzite	Stock	1940	88'
Eichel, H	NE	28	99	53	Bored	40'	8"	Tile		Drift	Till	House	?	30'
Costain, R	NW	28	99	53	Dug	16'	18"	Tile		Outwash	Sand, Grav	Stock	1896	13'
Chester, L	SE	31	99	53	Bored	65'	24"	Tile		Drift	Till	Stock	?	35'
Jenter, E	SE	32	99	53	Bored	51'	24"	Wood		Drift	Till	Stock	1940	40'
Jenter, E	SE	32	99	53	Bored	54'	30"	Concrete		Drift	Gravel	House	1956	40'

DOMESTIC WELL RECORDS

Owner or Tenant	Location ¼	Sec	T	R	Type Well	Well Depth	Well Dia.	Type of Casing	Height Above Sea Lev.	Geologic Source	Character of Material	Use of Water	Date Drill-ed	Depth to Water
Eggleston, D	NE	32	99	53	Bored	65'	6"	Steel		Drift	Till	Stock	1951	?
Marquette, H	SW	32	99	53	Drove	14'	1"	Steel		Outwash	Sand, grav.	House	1930	11'
Spomer, H	NE	33	99	53	Bored	240'	6"	Steel		Sioux Fm.	Quartzite	Stock	1938	?
Jensen, H	NW	34	99	53	Bored	52'	24"	Steel		Drift	Till	House	1940	32'
Larsen, E	NE	34	99	53	Drove	16'	1"	Steel		Outwash	Sand, grav.	House	1950	12'
Luden, J	SW	6	99	52	Drove	18'	1"	Steel		Outwash	Sand, grav.	Stock	1916	17'
Jurgens, H	SW	7	99	52	Bored	80'	6"	Steel		Drift	Till	House	?	70'
Engelkes, E	NE	13	99	52	Bored	100'	6"	Steel		Drift	Till	Stock	?	?
Buse, W	NW	19	99	52	Bored	71'	5"	Steel		Drift	Till	House	1940	17'
Crawford, C	SW	19	99	52	Bored	114'	4"	Steel		Sioux Fm.	Quartzite	House	1956	?
Otten, E	SW	29	99	52	Dug	14'	18"	Tile		Drift	Till	Stock	?	?
VanHove, H	SW	30	99	52	Dug	15'	20"	Steel		Outwash	Sand, grav.	House	1900	13'
Weeldreyer	NW	30	99	52	Bored	138'	6"	Steel		Sioux Fm.	Quartzite	Stock	1926	50'
Kost, C	SE	31	99	52	Bored	85'	2"	Steel		Drift	Till	House	1952	45'
Kost, C	SE	31	99	52	Bored	85'	2"	Steel		Drift	Till	House	1952	45'
Harms, R	NE	31	99	52	Bored	40'	4"	Steel		Drift	Till	House	1926	20'
Sigl, J	SE	32	99	52	Bored	211'	6"	Steel		Sioux Fm.	Quartzite	Stock	1937	?
Smit, G	SW	32	99	52	Bored	68'?	6"	Steel		Drift	Till	Stock	?	38'
Reese, J	SE	1	98	53	Drove	?	1"	Steel		Outwash	Sand, grav	Stock	1920	?
O'Keefe, W	SE	3	98	53	Bored	18'	1"	Steel		Outwash	Sand, grav.	House	1900	?
Eggleston, H	NE	3	98	53	Dug	28'	24"	Wood		Outwash	Sand, grav.	House	1916	12'
Rundell, M	NW	3	98	53	Drove	25'	1"	Steel		Outwash	Sand, grav.	House	1936	15'
Handel, M	SW	3	98	53	Drove	20'	2"	Wood		Outwash	Sand, grav.	Stock	?	?
Eggleston, H	NE	4	98	53	Bored	120'	6"	Steel		Drift	Till	Stock	1937	40'

DOMESTIC WELL RECORDS

Owner or Tenant	Location ¼	Sec	T	R	Type Well	Well Depth	Well Dia.	Type of Casing	Height Above Sea Lev.	Geologic Source	Character of Material	Use of Water	Date Drill-ed	Depth to Water
Handel, M	SE	4	98	53	Bored	22'	8"	Steel		Outwash	Sand, grav.	House	1954	8'
Benney, R	NW	5	98	53	Dug	25'	24"	Wood		Outwash	Sand, grav.	House	1918	12'
Benney, R	NW	5	98	53	Bored	34'	24"	Concrete		Outwash	Sand	Stock	1956	14'
Flyger, L	SW	5	98	53	Bored	65'	6"	Steel		Niobrara	Chalk	Stock	1936	20'
Flyger, L	SW	5	98	53	Dug	19'	36"	Steel	1309'	Outwash	Sand, grav.	House	1931	19'
Hansen, R	NE	6	98	53	Bored	65'	4"	Steel		Drift	Till	Stock	1916	?
Schrodermeir	SW	7	98	53	Drove	30'	1"	Steel		Outwash	Sand, grav.	House	1920	?
Christenson	SE	7	98	53	Bored	67'	3"	Steel		Niobrara	Chalk	House	1944	35'
Gustad, M	NE	7	98	53	Bored	60'	4"	Steel		Outwash	Sand, grav.	House	1951	15'
Sorenson, R	NW	8	98	53	Bored	40'	4"	Steel		Outwash	Sand, grav.	House	1900	15'
Jibben, D	SE	9	98	53	Bored	165'	2"	Steel		Drift	Till	Stock	1928?	?
Knutson, C	NE	9	98	53	Dug	30'	24"	Wood		Outwash	Sand, grav.	House	1936	14'
Mount, H	SW	9	98	53	Drove	30'	1"	Stock		Outwash	Sand, grav.	Stock	?	?
Pingrey, D	SE	10	98	53	Bored	59'	4"	Steel		Drift	Till	House	1908	17'
Eckhoff, H	NW	10	98	53	Dug	32'	20"	Wood		Outwash	Sand, grav.	Stock	1912	16'
Thompson, C	SE	15	98	53	Drove	30'	1"	Steel		Outwash	Sand, grav.	Stock	?	?
Newhauer, T	SW	15	98	53	Bored	30'	8"	Steel		Outwash	Sand, grav.	Stock	1945	8'
Falck, C	NW	15	98	53	Drove	19'	1"	Steel		Outwash	Sand, grav.	House	?	5'
Flyger, M	SE	16	98	53	Bored	60'	5"	Steel		Niobrara	Chalk	House	1944	16'
Sneiderman	NE	17	98	53	Bored	90'	4"	Steel		Drift	Till	House	1932	14'
Godsk, L	SE	17	98	53	Bored	100'	6"	Steel		Niobrara	Chalk	House	1951	20'
Finn, L	NE	19	98	53	Bored	36'	4"	Steel		Drift	Till	Stock	?	12'?
Hanson, C	NE	21	98	53	Dug	30'	24"	Tile		Drift	Till	Stock	?	18'
Hanson, C	NE	21	98	53	Dug	65'	60"	Steel		Drift	Till	Stock	?	30'

DOMESTIC WELL RECORDS

Owner or Tenant	Location ¼	Sec	T	R	Type Well	Well Depth	Well Dia.	Type of Casing	Height Above Sea Lev.	Geologic Source	Character of Material	Use of Water	Date Drilled	Depth to Water
Gocken, D	NE	22	98	53	Drove	?	1"	Steel		Outwash	Sand, grav.	House	?	?
Peterson, M	NW	22	98	53	Bored	80'	6"	Steel		Drift	Till	Stock	1953	?
Sanborn, J	SE	22	98	53	Drove	16'	1"	Steel		Outwash	Sand, grav.	Stock	?	10'
Flyger, L	SW	23	98	53	Drove	16'	1"	Steel		Outwash	Sand, grav.	House	1900	8'
Poley, F	SW	24	98	53	Drove	25'	1"	Steel		Outwash	Sand, grav.	House	1943	8'
Vandiezen, W	SW	25	98	53	Drove	12'	1"	Steel		Outwash	Sand, grav.	Stock	1930	10'
Nelson, A	SW	25	98	53	Drove	22'	3"	Steel		Outwash	Sand, grav.	Stock	1946	18'
Crosley, R	NE	25	98	53	Drove	18'	1"	Steel		Outwash	Sand, grav.	Stock	1954	6'
Luden, H	NE	25	98	53	Bored	8'	1"	Steel		Outwash	Sand, grav.	Stock	?	3'
Hurley Well	NE	27	98	53	Bored	30'	36"	Concrete		Outwash	Sand, grav.	City	1955	12'
Friman, B	SE	27	98	53	Bored	60'	6"	Steel		Drift	Till	Stock	?	12'
Wiebersick, H	NW	27	98	53	Bored	160'	3"	Steel		Drift	Till	Stock	1916	20'
Davis, J	NE	29	98	53	Dug	11'	48"	Concrete		Alluvium	Sand	Stock	1920	8'
Haines, W	NE	30	98	53	Drove	14'	1"	Steel		Outwash	Sand, grav.	Stock	1920	12'
Kost, D	NW	31	98	53	Drove	18'	1"	Steel		Outwash	Sand, grav.	Stock	?	?
Jorgenson, D	SW	32	98	53	Bored	180'	4"	Steel		Drift	Till	Stock	1900	20'
Jorgenson, R	NE	35	98	53	Bored	60'+	4"	Steel		Drift	Till	Stock	?	30'
Overgaard, C	SE	36	98	53	Drove	18'	1"	Steel		Outwash	Sand, grav.	House	1948	5'
Larson, M	NW	36	98	53	Drove	25'	1"	Steel		Outwash	Sand, grav.	Stock	1954	?
Peterson, H	NE	5	98	52	Drove	20'	1"	Steel		Outwash	Sand, grav.	Stock	1945	14'
Stoddard, L	SW	5	98	52	Bored	125'	4"	Steel		Drift	Till	Stock	1888	30'
Christenson	NE	5	98	52	Bored	50'	24"	Steel		Drift	Till	Stock	1925	47'
Andernacht, C	NW	5	98	52	Bored	22'	6"	Steel		Outwash?	Fine sand	House	1954	20'
Perry, J	SE	6	98	52	Bored	152'	4"	Steel		Drift	Till	Stock	1890	40'

DOMESTIC WELL RECORDS

Owner or Tenant	Location ¼	Sec	T	R	Type Well	Well Depth	Well Dia.	Type of Casing	Height Above Sea Lev.	Geologic Source	Character of Material	Use of Water	Date Drilled	Depth to Water
Freekes, B	NE	6	98	52	Drove	25'	1"	Steel		Outwash	Sand, grav.	Stock	?	23'
Ihnen, R	SE	7	98	52	Drove	12'	1"	Steel		Outwash	Sand, grav.	House	1944	6'
Jacobson, E	SE	7	98	52	Drove	19'	1"	Steel		Outwash	Sand, grav.	Stock	1900	18'
Stoddard, M	SE	8	98	52	Bored	150'	6"	Steel		Drift	Till	House	1943	27'
Bunger, E	NW	8	98	52	Drove	14'	1"	Steel		Outwash	Sand	Stock	1955	8"
Bunger, E	NW	8	98	52	Bored	150'	4"	Steel		Drift	Till	House	?	18'
Vietor, J	NE	8	98	52	Bored	128'	6"	Steel		Drift	Till	Stock	1946	25'
Stoddard, M	SW	9	98	52	Drove	21'	1"	Steel		Outwash	Sand	Stock	1906	18'
Vietor, P	NW	9	98	52	Bored	100'+	1"	Steel		Drift	Till	Stock	1924	?
Temple, J	NW	17	98	52	Bored	120'	8"	Steel		Drift	Till	House	1906	?
Schroedermeir	SE	17	98	52	Drove	14'	1"	Steel		Drift	Sand, grav	House	1921	10'
Hagenbuch, C	NE	18	98	52	Drove	14'	1"	Steel		Outwash	Sand, grav.	House	1948	12'
Rieners, R	SW	18	98	52	Drove	18'	2"	Steel		Outwash	Sand, grav.	House	1930	12'
Bagley, A	NW	18	98	52	Drove	20'	1"	Steel		Outwash	Sand, grav.	House	1911	?
Kuper, H	NE	19	98	52	Drove	18'	1"	Steel		Outwash	Sand, grav.	House	?	?
Jongeling, F	NE	19	98	52	Dug	25'	36"	Tile		Drift	Till	Stock	1916	?
Hagenbuch, C	NE	20	98	52	Drove	14'	1"	Steel		Outwash	Sand, grav.	Stock	1921?	12'
Fletcher, D	NE	21	98	52	Bored	110'	4"	Steel		Drift	Till	House	?	?
Knock, R	SW	21	98	52	Drove	16'	1"	Steel		Outwash	Sand, grav.	House	1917	13'
Schroedermier	NE	21	98	52	Bored	133'	3"	Steel		Drift	Till	House	1926	7'
Wiebesick, D	SW	22	98	52	Bored	147'	3"	Steel		Drift	Till	Stock	1916?	25'
Smit, A	SW	28	98	52	Drove	127'	4"	Steel		Drift	Till	House	1920	18'
Luden, H	SE	30	98	52	Drove	14'	1"	Steel		Outwash	Sand, grav.	House	1900	9'
Crosley, R	NE	31	98	52	Drove	18'	1"	Steel		Outwash	Sand, grav.	Stock	1900	10'

DOMESTIC WELL RECORDS

OWNER OR TENANT	LOCATION				TYPE	WELL	WELL	TYPE OF	HEIGHT ABOVE	GEOLOGIC	CHARACTER OF	USE OF	DATE DRILL-	DEPTH TO
	1/4	SEC	T	R	WELL	DEPTH	DIA.	CASING	SEA LEV.	SOURCE	MATERIAL	WATER	ED	WATER
BOOMGARDEN, H	SE	32	98	52	DROVE	24'	1"	STEEL		OUTWASH	SAND, GRAV.	STOCK	1900	14'
SMIT, A	NW	32	98	52	DROVE	16'	1"	STEEL		OUTWASH	SAND, GRAV.	STOCK	?	7'
FEENSTRA, S	NE	33	98	52	BORED	130'	6"	STEEL		DRIFT	TILL	STOCK	1910	25'
SATHER, O	SW	33	98	52	DROVE	14'	1"	STEEL		OUTWASH	SAND, GRAV.	STOCK	1952	13'
SMITH, W	SE	34	98	52	BORED	75'	8"	STEEL		DRIFT	TILL	HOUSE	1906	20'
SHADE, J	SW	34	98	52	BORED	14'	4"	STEEL		OUTWASH	SAND, GRAV.	NONE	1945	10'
DWYER, E	NW	1	97	52	BORED	80'	2"	STEEL		NIOBRARA	CHALK	STOCK	1900	?
LARSON, E	SE	1	97	52	BORED	70'	4"	STEEL		DRIFT	TILL	STOCK	1941	30'
BARTELS, H	NE	2	97	52	BORED	110'	3"	STEEL		DRIFT	SAND	STOCK	?	55'
MENNINGA, G	SW	2	97	52	BORED	70'	2-3"	STEEL		DRIFT	TILL	HOUSE	1913	16'
SMITH, W	NW	3	97	52	BORED	75'?	2-4"	STEEL		?	?	STOCK	?	?
HENKE, C	SE	3	97	52	DROVE	14'	1"	STEEL		OUTWASH	SAND, GRAV.	HOUSE	1949	12'
URBAN, F	SW	3	97	52	DROVE	12'	1"	STEEL		OUTWASH	SAND, GRAV.	HOUSE	1922	10'
FEENSTRA, R	NE	3	97	52	BORED	72'	4"	STEEL		DRIFT	TILL	HOUSE	1920	17'
BUUS, E	SW	4	97	52	DROVE	12'	1"	STEEL		OUTWASH	SAND	HOUSE	1924	8'
SNOOZY, J	SW	5	97	52	BORED	110'	3"	STEEL		DRIFT	TILL	HOUSE	1920	20'
BISHOP, F	NW	6	97	52	BORED	78'	4"	STEEL		DRIFT	TILL	STOCK	1941	30'
MCGINN, J	NW	8	97	52	BORED	110'	4"	STEEL		DRIFT	TILL	HOUSE	1936	?
MCGINN, W	NE	8	97	52	BORED	112'	4"	STEEL		DRIFT	TILL	HOUSE	1900	?
ERICKSON, D	SE	9	97	52	BORED	108'	3"	STEEL		DRIFT	TILL	HOUSE	1938?	57'
BLAKE, O	SE	11	97	52	BORED	150'	3"	STEEL		DRIFT	TILL	STOCK	?	?
ANDERSON, C	NW	11	97	52	BORED	85'	3"	STEEL		DRIFT	TILL	HOUSE	1920	?
VASGAARD, J	NW	14	97	52	BORED	55'	4"	STEEL		OUTWASH	SAND, GRAV.	NONE	1956	17'
JOHNKE, O	NW	15	97	52	BORED	160'	3"	STEEL		DRIFT	TILL	HOUSE	1900	?
LARSON, C	SW	31	97	52	DROVE	15'	1"	STEEL		OUTWASH	SAND, GRAV.	STOCK	?	?

RESISTIVITY DATA ON THE THICKNESS OF SAND AND GRAVEL

Sta. No.	Location	Elevation Sea Level Surface	Thickness (feet) Sand & Gravel	Overburden
A 1	NW$\frac{1}{4}$SW$\frac{1}{4}$ Sec. 7, T98N., R53W.,		0	
B 1	NW$\frac{1}{4}$SW$\frac{1}{4}$ Sec. 8, T98N., R53W.,		0	
B 2	SE$\frac{1}{4}$SW$\frac{1}{4}$ Sec. 5, T98N., R53W.,	1304.0	31	6
B 3	SE$\frac{1}{4}$NE$\frac{1}{4}$ Sec. 6, T98N., R53W.,		0	
C 1	SW$\frac{1}{4}$SW$\frac{1}{4}$ Sec. 9, T98N., R53W.,		0	
C 2	SE$\frac{1}{4}$SE$\frac{1}{4}$ Sec. 5, T98N., R53W.,	1295.4	40*	6
C 3	SW$\frac{1}{4}$NW$\frac{1}{4}$ Sec. 4, T98N., R53W.,	1308.0	55*	17
D 1	SW$\frac{1}{4}$SW$\frac{1}{4}$ Sec. 15, T98N., R53W.,	1269.1	0	
D 2	NW$\frac{1}{4}$NW$\frac{1}{4}$ Sec. 15, T98N., R53W.,	1275.4	0	
D 3	NW$\frac{1}{4}$NW$\frac{1}{4}$ Sec. 10, T98N., R53W.,	1278.5	0	
D 4	SE$\frac{1}{4}$SE$\frac{1}{4}$ Sec. 4, T98N., R53W.,	1284.9	15	3
D 5	SE$\frac{1}{4}$SE$\frac{1}{4}$ Sec. 33, T98N., R53W.,		0	
D 6	NW$\frac{1}{4}$NW$\frac{1}{4}$ Sec. 34, T99N., R53W.,		0	
D 7	NW$\frac{1}{4}$NW$\frac{1}{4}$ Sec. 15, T99N., R53W.,		48	2
E 1	SW$\frac{1}{4}$SW$\frac{1}{4}$ Sec. 23, T98N., R53W.,	1261.8	62?	
E 2	SE$\frac{1}{4}$NE$\frac{1}{4}$ Sec. 22, T98N., R53W.,	1266.4	30	
E 3	SW$\frac{1}{4}$SW$\frac{1}{4}$ Sec. 11, T98N., R53W.,	1274.1	35	2.5
E 4	SW$\frac{1}{4}$SW$\frac{1}{4}$ Sec. 2, T98N., R53W.,	1281.5	80	0.5
E 5	NW$\frac{1}{4}$NW$\frac{1}{4}$ Sec. 2, T98N., R53W.,	1289.0	52	0.5
E 6	SW$\frac{1}{4}$SW$\frac{1}{4}$ Sec. 26, T99N., R53W.,	1297.4	70	2
E 7	NW$\frac{1}{4}$NW$\frac{1}{4}$ Sec. 26, T99N., R53W.,	1303.9	58	2

Sta. No.	Location	Elevation Sea Level Surface	Thickness (feet)	
			Sand & Gravel	Overburden
E 8	NW¼NW¼ Sec. 23, T99N., R53W.,	1310.5	50*	5
E 9	SW¼NW¼ Sec. 14, T99N., R53W.,	1304.9	60*	
E10	NW¼NW¼ Sec. 14, T99N., R53W.,	1305.6	0	
F 1	NE¼NE¼ Sec. 35, T98N., R53W.,	1253.9	27	3.5
F 2	SE¼NE¼ Sec. 23, T98N., R53W.,	1261.0	40	3.0
F 3	SE¼SE¼ Sec. 14, T98N., R53W.,	1266.4	60*	2.0
F 4	NW¼NW¼ Sec. 13, T98N., R53W.,	1274.7	60*	1.5
F 5	NW¼NW¼ Sec. 12, T98N., R53W.,	1277.7	70*	3.0
F 6	SE¼SE¼ Sec. 35, T99N., R53W.,	1287.9	52	1.0
F 7	SE¼SE¼ Sec. 26, T99N., R53W.,	1293.9	50	1.5
F 8	NE¼NE¼ Sec. 26, T99N., R53W.,	1299.1	45	
F 9	NE¼NE¼ Sec. 23, T99N., R53W.,	1304.5	65	1.5
G 1	SE¼SE¼ Sec. 36, T98N., R53W.,		20	3.0
G 2	NE¼NE¼ Sec. 36, T98N., R53W.,	1248.6	30	2.0
G 3	SE¼SE¼ Sec. 24, T98N., R53W.,	1254.1	55*	1.5
G 4	NE¼NE¼ Sec. 24, T98N., R53W.,	1264.9	67	2.0
G 5	NE¼NE¼ Sec. 13, T98N., R53W.,	1271.4	90	2.5
G 6	NE¼NE¼ Sec. 12, T98N., R53W.,	1277.8	55	3.0
G 7	NE¼NE¼ Sec. 1, T98N., R53W.,	1284.3	52	3.0
G 8	NE¼NE¼ Sec. 36, T99N., R53W.,	1287.8	55	3.0
G 9	NW¼NW¼ Sec. 30, T99N., R52W.,		27	
G10	SW¼SW¼ Sec. 18, T99N., R52W.,		0	
H 1	NE¼SE¼ Sec. 6, T97N., R52W.,	1243.8	?	5.0

Sta. No.	Location	Elevation Sea Level Surface	Thickness (feet)	
			Sand & Gravel	Overburden
H 2	SE$\frac{1}{4}$NE$\frac{1}{4}$ Sec. 6, T97N., R52W.,	1245.2	22?	
H 3	SW$\frac{1}{4}$SW$\frac{1}{4}$ Sec. 29, T98N., R52W.,	1253.4	45	3.0
H 4	NE$\frac{1}{4}$NE$\frac{1}{4}$ Sec. 30, T98N., R52W.,	1258.0	65	4.0
H 5	SE$\frac{1}{4}$SE$\frac{1}{4}$ Sec. 18, T98N., R52W.,	1265.1	35	3.5
H 6	SW$\frac{1}{4}$SW$\frac{1}{4}$ Sec. 8, T98N., R52W.,	1265.5	50	6.0
H 7	NE$\frac{1}{4}$NE$\frac{1}{4}$ Sec. 7, T98N., R52W.,	1268.0	?	
H 8	NE$\frac{1}{4}$NE$\frac{1}{4}$ Sec. 6, T98N., R52W.,		0	
H 9	NE$\frac{1}{4}$SE$\frac{1}{4}$ Sec. 31, T99N., R52W.,		0	
I 1	NW$\frac{1}{4}$SW$\frac{1}{4}$ Sec. 4, T97N., R52W.,	1242.6	60*	1.0
I 2	SW$\frac{1}{4}$SW$\frac{1}{4}$ Sec. 33, T98N., R52W.,	1250.5	70*	6.0
I 3	SE$\frac{1}{4}$SE$\frac{1}{4}$ Sec. 29, T98N., R52W.,	1253.7	60*	4.0
I 4	SW$\frac{1}{4}$SW$\frac{1}{4}$ Sec. 21, T98N., R52W.,	1257.8	60*	2.0
I 5	NW$\frac{1}{4}$NW$\frac{1}{4}$ Sec. 21, T98N., R52W.,	1264.9	70*	1.0
I 6	NE$\frac{1}{4}$NE$\frac{1}{4}$ Sec. 17, T98N., R52W.,	1270.6	32	6.0
I 7	NW$\frac{1}{4}$NW$\frac{1}{4}$ Sec. 9, T98N., R52W.,		0	
J 1	NW$\frac{1}{4}$NW$\frac{1}{4}$ Sec. 10, T97N., R52W.,		50*	5.0
J 2	NE$\frac{1}{4}$SE$\frac{1}{4}$ Sec. 4, T97N., R52W.,		38	
J 3	SE$\frac{1}{4}$SE$\frac{1}{4}$ Sec. 33, T98N., R52W.,	1246.0	50*	5.0
J 4	SE$\frac{1}{4}$SE$\frac{1}{4}$ Sec. 28, T98N., R52W.,	1252.2	40*	4.0
J 5	NW$\frac{1}{4}$NW$\frac{1}{4}$ Sec. 27, T98N., R52W.,	1255.6	28	4.0
J 6	NE$\frac{1}{4}$NE$\frac{1}{4}$ Sec. 21, T98N., R52W.,		42	5.0
K 1	SE$\frac{1}{4}$SE$\frac{1}{4}$ Sec. 10, T97N., R52W.,		50*	
K 2	NW$\frac{1}{4}$NW$\frac{1}{4}$ Sec. 11, T97N., R52W.,		55*	1.5

* Indicates bottom of gravel was not reached due to operational failure of resistivity gradiometer. Information obtained from nearby drill hole.

WELL LOGS IN OUTWASH SEDIMENTS

SURVEY TEST HOLE T1

LOCATION: SE$\frac{1}{4}$ SW$\frac{1}{4}$ SEC. 10, T98N., R53W., TURNER COUNTY
OWNER: PUBLIC PROPERTY

DRILLER: STATE SURVEY
ELEVATION: 1272
TOTAL DEPTH: 44 FEET

DEPTH (FEET)	DESCRIPTION
0 - 4	TOPSOIL AND FINE SAND
4 - 9	FINE SAND, WATER AT 6 FEET
9 - 14	MED. SAND AND WATER
14 - 19	MED. SAND AND WATER
19 - 24	MED. SAND AND WATER
24 - 29	MED. SAND AND WATER
29 - 34	MED. SAND AND WATER TO 30 FEET; 30 TO 34 FEET TILL AND MED. SAND
34 - 39	FINE GRAY GRAVEL AND CLAYEY TILL
39 - 44	CLAYEY TILL

Survey Test Hole T2

Location: SW¼ Sec. 19, T97N., R51W., Lincoln County
Owner: Public Property

Elevation: 1219
Total Depth: 64 feet
Driller: State Survey

Depth (feet)	Description
0 - 4	Topsoil
4 - 9	Med. sand, water at 8 feet
9 - 14	Coarse sand
14 - 49	Fine gravel, very well sorted
49 - 54	Same as above with a clay parting
54 - 64	Fine gravel, very well sorted

Survey Test Hole T3

Location: SE¼ SW¼ Sec. 8, T98N., R52W., Turner County
Owner: Public Property

Driller: State Survey
Elevation: 1271
Total Depth: 43 feet

Depth (feet)	Description
0 - 4	Topsoil
4 - 14	Sandy clay (alluvium)
14 - 19	Med. sand, water at 17 feet
19 - 41	Fine to med. gravel
41 - 43	Dark blue clay

Survey Test Hole T4

Location: NW¼ NW¼ Sec. 3, T97N., R52W., Turner County
Owner: Public Property

Driller: State Survey
Elevation: 1247
Total Depth: 59 feet

Depth (feet)	Description
0 - 3	Black topsoil
3 - 4	Brown buff, sandy soil
4 - 9	Very fine, brown, moist sand
9 - 14	Fine sand, water at 10 feet
14 - 49	Fine sand with water
49 - 59	Fine sand and some clay

Survey Test Hole T5

Location: NE¼ NE¼ Sec. 9, T97N., R52W., Turner County
Owner: Public Property

Driller: State Survey
Elevation: 1238
Total Depth: 64 feet

Depth (feet)	Description
0 - 4	Road fill
4 - 9	Dark brown sandy silt, water at 9 feet
9 - 34	Fine gravel and water
34 - 44	Coarse sand and fine gravel
44 - 64	No cuttings came to surface, however when the augers were brought to the surface they were all clean and wet indicating they were probably drilling in gravel containing much water

Survey Test Hole T6

Location: NW¼ SW¼ Sec. 28, T98N., R52W., Turner County
Owner: Public Property

Driller: State Survey
Elevation: 1251
Total Depth: 49 feet

Depth (feet)	Description
0 - 7	Humus and topsoil
7 - 9	Med. gravel
9 - 14	Med. to fine gravel, water at 12 feet
14 - 19	Coarse sand
19 - 24	Med. sand
24 - 29	Coarse to med. sand
29 - 34	Med. to fine sand
34 - 48	Fine sand
48 - 49	Clay and sand

Survey Test Hole T7

Location: SE$\frac{1}{4}$ NE$\frac{1}{4}$ Sec. 6, T97N., R52W., Turner County
Owner: Public Property

Driller: State Survey
Elevation: 1247
Total Depth: 64 feet

Depth (feet)	Description
0 - 3	Topsoil
3 - 14	Med. gravel to coarse sand, water at 7 feet
14 - 29	Fine to med. gravel
29 - 34	Same as above with some coarse gravel
34 - 39	Fine gravel
39 - 44	Fine to med. gravel
44 - 61	Med. gravel
61 - 64	Coarse sand

Survey Test Hole T8

Location: SW$\frac{1}{4}$ Sec. 33, T96N., R52W., Turner County
Owner: Public Property

Driller: State Survey
Elevation: Unknown
Total Depth: 69 feet

Depth (feet)	Description
0 - 14	Fine sand, water at 14 feet
14 - 19	Med. sand
19 - 39	Coarse sand
39 - 54	Fine gravel
54 - 59	Med. sand
59 - 69	Fine sand

Irrigation Test Hole W1

Location: 80 rods east of center NE$\frac{1}{4}$ Sec. 35, T99N., R53W., Turner County
Owner: Bones Hereford Ranch

Driller: Maxwell & Grimshaw
Elevation: 1297
Total Depth: 35 feet

Depth (feet)	Description
0 - 2	Topsoil
2 - 6	Sand
6 - 34	Sand & gravel, water at 15 feet
34 - 35	Blue clay

Irrigation Test Hole W2

Location: Center NW¼ Sec. 11, T98N., R53W., Turner County
Owner: Harry Novak

Driller: Maxwell & Grimshaw
Elevation: 1273
Total Depth: 72 feet

Depth (feet)	Description
0 - 1½	Topsoil
1½ - 7	Fine sand
7 - 72	Sand and gravel, water at 10 feet

Irrigation Test Hole W3

Location: Center SE¼ Sec. 20, T98N., R52W., Turner County
Owner: Harm Hagena

Driller: Maxwell & Grimshaw
Elevation: 1259
Total Depth: 50 feet

Depth (feet)	Description
0 - 2	Topsoil
2 - 4	Fine sand
4 - 10	Sand and gravel
10 - 50	Sand, water at 12 feet
50	Blue clay

Irrigation Test Hole W4

Location: Center NE¼ Sec. 12 T98N., R53W., Turner County
Owner: Claude Sherard

Driller: Maxwell & Grimshaw
Elevation: 1286
Total Depth: 45 feet

Depth (feet)	Description
0 - 1½	Topsoil
1½ - 7	Fine, red sand
7 - 10	Gravel
10 - 45	Sand & gravel, water at 22 feet

Irrigation Test Hole W5

Location: NE¼ Sec. 23, T99N., R53W., Turner County
Owner: Roy Costain

Driller: Maxwell & Grimshaw
Elevation: Unknown
Total Depth: 43 feet

Depth (feet)	Description
0 - 2	Topsoil
2 - 8	Coarse gravel
8 - 43	Sand & gravel, water at 10 feet
43	Blue clay

Irrigation Test Hole W6

Location: Center SE¼ Sec. 26 T98N., R53W., Turner County
Owner: Chris Flyger

Driller: Maxwell & Grimshaw
Elevation: 1262
Total Depth: 55 feet

Depth (feet)	Description
0 - 2	Topsoil
2 - 5	Clay and sand
5 - 43	Sand, water at 12 feet
43 - 55	White sand
55	Blue clay