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REPORT OF INVESTIGATIONS

NO. 80

GEOLOGY AND SHALLOW WATER RESOURCES OF THE BLUE BLANKET VALLEY AND HOVEN OUTWASH, POTTER COUNTY SOUTH DAKOTA

by

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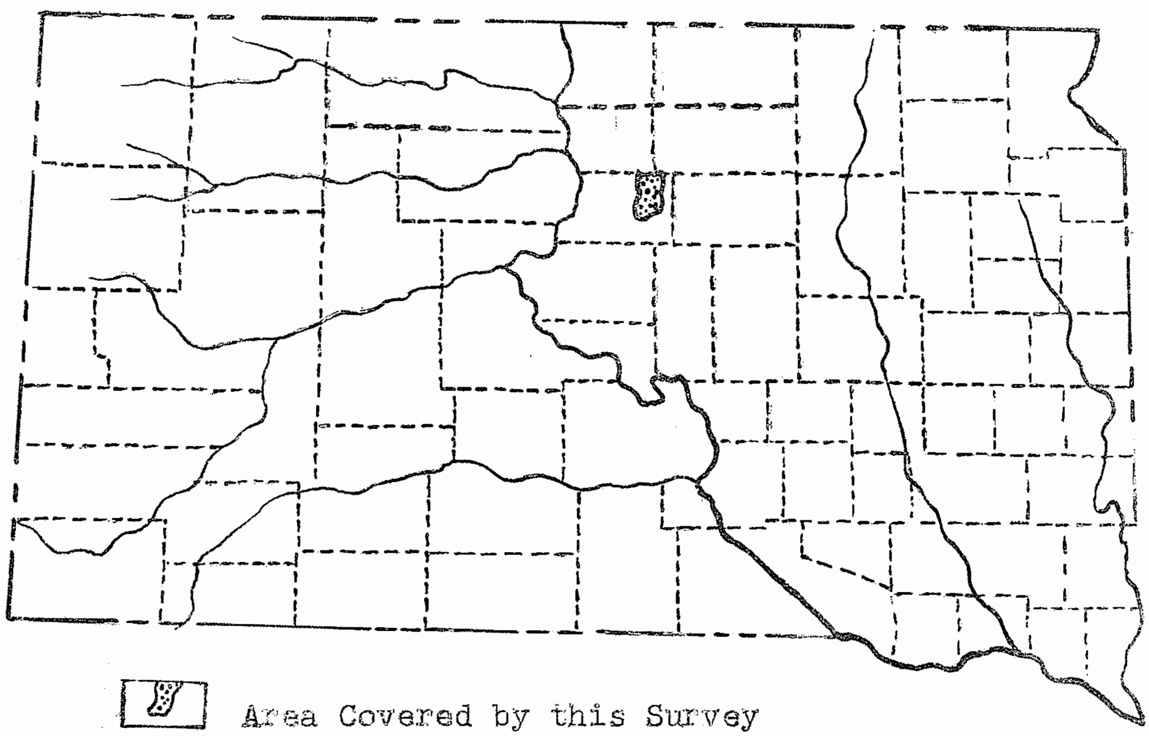
INDEX MAP



GEOLOGY AND SHALLOW WATER RESOURCES OF THE BLUE BLANKET VALLEY AND HOVEN OUTWASH, POTTER COUNTY SOUTH DAKOTA

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INTRODUCTION

PURPOSE AND SCOPE OF THE INVESTIGATION

This report is one of the systematic investigations of water resources undertaken by the State Geological Survey of South Dakota. In the region of the Blue Blanket Valley and Hoven Outwash, the frequent drought seasons cause repeated crop failures, and an interest in irrigation from shallow wells in this region has been taken into consideration.

The field work was done during the summer season of 1955. This investigation was made to (1) decipher shallow water condition, and determine quantity, movement and availability of this water, and the feasibility of further development of irrigation from shallow wells; (2) to take the account of outwash sediments as well as their physical characters in relation to the irrigation and construction purposes. It is hoped that the data given herein will facilitate the development of the shallow water resources of this region.

LOCATION AND EXTENT OF THE AREA

The area (Index Map) lies about seven miles east of Gettysburg, and embraces the Blue Blanket Valley and the southern portion of Hoven Outwash[8]. The Blue Blanket Valley, which was named after a local Indian chief, extends north-south twelve miles and east and west four miles. The total area roughly covers eighty square miles (Plate 1). It occupies nearly half of townships 118 and 119 in ranges 74 and 75 west, Potter County. The city of Lebanon is located at its southern end.

The Hoven Outwash lies immediately north of the Blue Blanket Valley in townships 120 and 121 north, ranges 74 and 75 west, Potter and Walworth Counties. Swan Lake lies in its northern end and the city of Hoven near its center.

PREVIOUS INVESTIGATIONS

During the past decades this region had been investigated by several outstanding geologists. In 1896, James E. Todd[8], first State Geologist to the State of South Dakota, studied the glacial features and drift exposed at the surface. In the summer season of 1926, E. P. Rothrock[6], in cooperation with the State Highway Commission of South Dakota, carried out a more accurate mapping and description of the glacial features; he also gave a more detail account on the location, resources, and physical characters of the outwash sediments. During the summer, 1954, A. Stoley and A. Miller spent several weeks in the Blue Blanket Valley, and studied the outwash sediments by the method of electric soundings. Their results furnished valuable information for the present study. In the successive summer seasons from 1946 to 1949, R. F. Flint[1], made a reconnaissance study on the Pleistocene Geology of eastern South Dakota, and passed through this region; his study threw a new light on the chronology of glacial sediments.

METHOD OF INVESTIGATION

The field work was done by the cooperation of a geologist and a geophysicist. Electric soundings were used to ascertain the thickness of outwash sediments and the amount of water available. The area was first examined by the geologist, who determined general scope of the investigation, and in conference with the geophysicist, decided the locations of the resistivity stations.

A topographic and geologic map was made by plane table surveying, on a scale 1:2500, using a contour interval of five feet. The locations and elevations of domestic water wells and resistivity stations were plotted on the map. A hand auger was used to determine the thickness of overburden materials as well as the accurate boundary of outwash sediments. The records of three domestic dug wells were obtained from the farmers of Lebanon and Hoven. Thickness of sand and gravel was carefully checked with the results of electric soundings.

Textural study on sand and gravel was made in the laboratory of the State Geological Survey.

ACKNOWLEDGMENTS

The writer is indebted to Dr. E. P. Rothrock for his encouragement in carrying out this work and to Prof. T. H. Bedwell, State Teacher's College, Springfield, South Dakota for his enthusiastic cooperation in the determination of thickness of sand and gravel by the electric sounding method.

During the field work, the writer was assisted by D. L. Walter, and partly by J. G. Larson and S. Graf. They gave much

help in the collection of the field data.

Special thanks are due to the residents of this region for their valuable help in furnishing information on their water wells.

GEOGRAPHY

TOPOGRAPHY AND DRAINAGE

Glacial features are remarkably well-developed in this region (Plate 1). The maximum relief is 145 feet. The highest elevation is located in the southeastern portion of the area while the lowest relief occurs in the northwestern corner of this region. Generally speaking, the topography ranges from gently sloping flat areas of fine silts and sands through an undulating surface with kettles and sloughs to the rough land forms of an end moraine, which are dotted through the eastern part of this region, and are well-developed along the front portion of the Lebanon end moraine (Rothrock, 1932)[6].

The Blue Blanket Valley is an elongated oval-shaped depression, and covers around fifty-two square miles. It was formed by two massive end moraines during the early part of the Wisconsin glaciation. Its outer edge lies three miles west of the Lebanon end moraine. In this valley the maximum relief is 110 feet from the top of the moraine to the bottom of the valley.

Along the eastern rim of the Blue Blanket Valley, a sheet-shaped outwash surface, trending north-south, slopes down gently toward the eastern bank of an intermittent stream in the western portion of this region. This surface extends northward to the vicinity of Hoven and forms the main portion of Hoven Outwash.

The undulating landforms consist of numerous ice-contact features, kames and eskers, which are well-displayed along the front of the Lebanon end moraine. The kames were left as rounded hills, while the eskers remained as ridges with undulating crest lines, where proglacial tunnels and crevices had existed during the stage of ice retreat. Undrained depressions, knobs and kettles in close association with the kame and esker fields, are scattered through the eastern portion; the drained depressions are generally present on the west. Terraces of sand and gravel are well-developed in the western portion of this region.

The drainage system is entirely controlled by the glaciation, which plays a major role in determination of the portion and direction of flow of surface water as well as shallow water bodies. There is a main intermittent stream running through the western portion of this region which flows in a northwesterly direction and empties into Swan Lake. Numerous isolated depressions intercept the course of this stream, which has an intricate pattern as it meanders over its own alluvium and glacial fluvial sediments. Several obscure tributary channels drain down to this main stream from both sides. The tributary system to the west is comparatively well-intergraded to that on the east. Two artificial dam sites were built along the stream for the purpose of storage of water for private irrigation. These dam sites locally stabilize the shallow ground water level.

CLIMATE

In this region there is a typical continental climate with typically hot summers and cold winters, and rapid fluctuation of temperature. During the summer season temperatures of 100° F. or more are not uncommon. In the winter months temperature is usually below zero, the lowest winter temperature was recorded as -22° F. in 1940. As a whole, the annual mean temperature from 1932 to 1954 was 44.8° F. (Table 1).

The rainfall record (Table 1) is interesting because it directly influences the amount of shallow ground water. According to the U. S. Weather Bureau, the dryest seasons occurred from 1933-1937. The lowest annual precipitation, 8 inches, was recorded in 1934. The highest record was 23.62 inches in 1953. The intensity of the dry seasons has been comparatively less in the past several years. From 1932 to 1954 the records indicate May, June and August are the wet months, while November, December and January are the dry months.

TABLE 1

ANNUAL AND MONTHLY AVERAGE PRECIPITATIONS AND MEAN TEMPERATURES
1932-1954
(Data based on the records issued by the U. S. Weather Bureau)

Year	Precipitation (inches)	Temperature (F°)	Month	Precipitation (inches)
1932	17.48	44.6	January	0.51
1933	12.65	47.7	February	1.91
1934	8.00	48.7	March	1.01
1935	10.32	44.6	April	1.58
1936	9.88	43.1	May	2.22
1937	13.69	42.0	June	3.65
1938	15.42	46.2	July	1.94
1939	15.65	47.0	August	2.73
1940	11.33	44.7	September	1.20
1941	19.89	46.5	October	0.93
1942	21.94	44.5	November	0.505
1943	15.17	44.6	December	0.308
1944	18.78	44.7		
1945	16.21	44.1	Total	17.76
1946	22.00	46.1		
1947	13.69	45.0		
1948	20.08	44.4		
1949	17.18	44.4		
1950	14.69	40.4		
1951	17.43	41.1		
1952	18.70	45.2		
1953	23.62	46.3		
1954	14.34	46.5		

POPULATION AND AGRICULTURE

The human population is sparse and concentrates in two towns, Hoven and Lebanon. Farming is the chief occupation with corn the chief crop. Cattle and hog feeding is very common.

The soil is usually dark brown. The main vegetation is grass. Due to the scanty moisture in this region, the grass is not the heavy stand type. The calcium carbonate (lime) is generally leached from the upper part of the soil profile down to local depths of from 0.4 to 2 feet. According to the information given by local farmers, in most moist years the land is highly productive, but during dry years, crops and stock meet a very difficult situation.

GEOLOGY

STRATIGRAPHY

General Setting

The regional geology (Plates 1 & 3 and Table 2) is made up chiefly of Wisconsin glacial sediments, which are tentatively subdivided into two groups: Iowan and Cary[1]. The Wisconsin drift consists of till, outwash, ice-contact stratified sediments, and outwash-margin lake deposits and alluvium; of these the outwash and ice-contact stratified sediments are predominant, while till and outwash-margin lake deposits and alluvium are subordinate. Scattered recent alluvial deposits occur along the main intermittent streams.

Outcrops of bedrock show the Pierre formation, which is sporadically exposed along both sides of the Simon's dam site in the Section 29, T120N, R74W. Due to the poor exposures, the writer has made no attempt to correlate these outcrops with Searight's[7] subdivisions.

TABLE 2

GENERALIZED GEOLOGIC SECTION FOR THE BLUE BLANKET VALLEY AND HOVEN OUTWASH

System	Series	Stage	Sub-Stage	Description	Thickness (feet)	Remarks
QUATERNARY	Recent			Alluvium: clay, silt and sand	0-5	As transmitting agent in recharge to ground water
	PLEISTOCENE	WISCONSIN	Cary	Outwash-margin lake deposits and alluvium: parallel bedded clay, silt and sand	0-7	
				Valley train: sand and gravel with silt	1.5-35	Chiefly yield water to wells when saturated
				Outwash: sand and gravel mainly	1.5-111	
				Ice-contact stratified sediments: sand and gravel with silt	2-?	
				Till, boulder clay, with rounded rock fragments; cemented by clay, with sand and silt matrix. Yellowish buff silt occasionally on top. Calcareous	10-25?	Yield abundant supplies of water and also as transmitting medium in upland areas
			Iowan	Till, chiefly of silt and clay frequently with rounded pebbles and boulders. Yellowish brown, silty loess occurs locally. Calcareous	3-35?	
		Major Hiatus				
Mesozoic	Cretaceous	Montana	Pierre Formation	Shales, bluish gray to blackish gray, fissile well-laminated	1-34	Not a main source of water supply

Cretaceous System

Pierre Formation

The Pierre formation consists of bluish gray to blackish gray, light gray when weathered, fissile, well-laminated shales. It is the only bedrock formation exposed in this region. Scattered patches of bentonitic materials are present in the upper part of this formation. Generally at the surface it contains a 9 inch zone of poorly developed soil, which is dark in color with considerable moisture. The maximum exposed thickness is 34 feet along the eastern side of the Simon's dam site.

The surface of the Pierre shale on which the mantle rock sediments rest, was produced by preglacial erosion, and consists of valleys and intervalley ridges that are concealed beneath the Wisconsin drift. According to the geophysical data, those land surfaces were more rugged than the present surface. The regional slope of the Pierre shale surface is east-northward.

This shale is relatively impermeable, and it will not develope a supply of ground water. Consequently, no further consideration is given it in this report.

Pleistocene System

Wisconsin Drift

During the Pleistocene time eastern South Dakota was completely covered by the Wisconsin drift. This drift is spread as a blanket over the eroded surface of the Pierre shale. Two successive drift sheets were recognized in this region, and tentatively subdivided into two groups, Iowan and Cary, respectively.

The Iowan drift consists chiefly of till with clay, silt and sand through which pebbles and boulders are scattered. The Cary drift is composed of boulder clay with silt and sand-rich matrix. In addition to these, ice-contact stratified sediments, outwash materials and outwash-margin lake deposits and alluvium, were formed during the period of Cary ice retreat.

Iowan Group:- The Iowan drift is well-exposed in the western part of this region, and an inferred demarcation between this drift and Cary Outwash is marked by the course of the main intermittent stream (Plate 1). This drift was completely examined along the western side of the Simon's dam site. Numerous hand-auger drilling holes, which penetrated up to 4.5 feet were made to determine the depth of the leached zone and the distribution of this drift. The thickness of drift ranges from 3 feet to 35 (?) feet. The lithologic description is summarized below in descending order:

Upper Part	Soil, brownish dark to dark, with average leached zone 19.8 inches......0.92-2.7 ft.
	Clay, gray to black, silt-rich frequently with numerous white patches of bentonitic materials, which consist chiefly of nontronite..........................3-? ft.
	Silt, or silty loess, yellowish brown to buff, with a considerable amount of medium-grained sand. Aggregates of clear quartz crystals are scattered through the mass. Exposed locally ....0-3.4 ft.
Lower Part	Till, gray to greenish gray and olive-brown when moist, somewhat dusky yellow when dry. Pebbles are common and in a silt-rich matrix. Medium to coarse grained sands are present in a fair amount..12± ft.
	Till, black, consisting of boulders and cobbles with some fine-grained matrix, numerous contorted lenticular inclusions of sand, silt, clay and pebbles........15± ft.

The rounded rock fragments found in this drift, consist of igneous and metamorphic rock types, plus Paleozoic limestones and dolomites, and some Cretaceous Pierre shale. Topographically, this drift is almost devoid of undrained basins and has a well-intergraded drainage pattern.

Cary Group:- The Cary drift covers the eastern portion of this region, and acted as the chief source of the outwash sediments. It is topographically characterized by a poorly drained surface and large numbers of closed depressions. A concise lithological description is based on numerous hand auger profiles along the road cuts of U. S. Highway 212.

Upper Part	Soil, darkish brown, with average leached zone of 9 inches..............0.4-1 ft.
	Clay, gray to blackish gray, with numerous white patches of bentonitic materials - chiefly of nontronite........0.5-1.3 ft.
	Silt, orange brown, yellowish gray with a considerable amount of fine-to-medium-grained sand. Aggregates of clear quartz crystals are present in the lower part... 0-2.5 ft.
Lower Part	Till, "boulder clay", bluish gray to black and olive green when moist, yellowish gray

to gray when dry; with abundant pebbles, boulders and cobbles in silt-rich matrix.... 2.5-5 ft.
Till, bluish gray to olive green consisting chiefly of stone fragments with a considerable amount of clay and silt.......5-12 ? ft.

Stratified Drift:- Stratified drift is generally distinct from till in that it has been both sorted and stratified by melted ice-water after or before its release from the ice. In this region these sediments are widely distributed, and occasionally grade into till. Under this category are included ice-contact stratified sediments, outwash materials, including valley train, and outwash-margin lake deposits and alluvium.

Ice-Contact Stratified Sediments:- These sediments are distributed between the main outwash mass and the front of the Lebanon end moraine. They are well-developed in the upstream parts of the main outwash mass, and represented by eskers and kames. These land forms are well-located in Sections 2 and 12, T18N, R74W; Sections 4, 9, 16, 22, 27, and 35, T119N, R74W, and Sections 3, 10, 14, 15, 22, 23, 26, 27 and 34, T120N, R74W; they were formed along the depressions and tunnels during the last stage of ice retreat. Both eskers and kames are filled with sand and gravel. In association with eskers and kames, kettle-holes are common; they are the closed depressions created by the melting out of buried or partly buried blocks of ice after sedimentation had ceased at the site of the kettle.

Outwash Sediments:- On the outer margin of the Lebanon end moraine, a sheet-shaped outwash plain spread in a northwesterly direction over the pre-Cary erosion surface. It was formed as a series of coalescent fans whose individual apices are still recognizable. According to the configuration of distribution, this outwash body is subdivided into two parts: main outwash plain and valley train.

The main outwash plain is a merging of the ice-contact stratified sediments, and covers the major part of this region. It consists of sand, gravel and some silt and clay (see Well Logs in the Appendix). Oxidized materials in patches are occasionally scattered through the mass. These sediments were carried by the ice-melt water through the pre-moraine valleys and intermoraine depressions, which were leading directly away from the Lebanon end moraine.

There are seven pre-moraine valleys which are tentatively indicated by the geophysical soundings. The first leads away from the southeastern corner of Section 12, T118N, R74W, through Sections 11, 10 and 4, T118N, R74W, and terminates in Section 5, T118N, R74W. The average thickness of sand and gravel filling is 13 feet. The second is due east of Lebanon, its upstream portion is located in Section 2, T118N, R74W and connects with the first in the vicinity of Lebanon. Average thickness of sand and gravel is 27 feet. The third is located between Sections 27 and 22, 28 and 21, T119N, R74W. The outwash materials were carried down in westerly and northwesterly directions. Average thickness of sand and gravel filling in this fan is 17 feet. The fourth emerges from the southeastern corner of Section 16, T119N, R74W. The outwash sediments were spread due northwesterly through the main portion of Section 9, T119N, R74W. Average thickness of sand and gravel is 11 feet. The fifth is one of the largest pre-moraine valleys in this region and comparatively deeper and wider than those described. It is situated in Sections 28, 34, 33, and 27, T120N, R74W. The north rim of this valley is located between Sections 21 and 22, T120N, R74W. The maximum depth is indicated as 111 feet at the northeastern corner of Section 28, T120N, R74W. The average thickness of sand and gravel fill is 63 feet. The sixth is mainly located in the Sections 21, 22, 15, and 16, and has an average fill of sand and gravel of 34 feet. The seventh originated in Section 4, T120N, R74W and through the site of present Sections 5, 8, and 9, T120N, R74W. The average thickness of sand and gravel filling is 52 feet.

The upper portions of these valleys were conspicuously filled by the ice-contact stratified drift. In consequence, the outwash was built near the mouths of those pre-moraine valleys in delta-like forms, and was carried away along the old channel of the present main intermittent stream. As the result of this type of filling, the valley train was formed. Valley train sediments are comparatively smaller in size and contains rather abundant shale fragments. Because of the effects of selective transportation, the average size of the particles decreases in the direction of transport; this fact is partly the result of a gradual diminution in turbulence intensity downstream.

During the last stage of ice retreat the overflow passing over the older outwash mass was underloaded so that instead of adding to the outwash, it trenched it. The valley train so trenched was left as the sand and gravel terraces along the valley side. Subsequently, the nonglacial streams reoccupying the valleys filled with outwash, carved the outwash mass into stream terraces with decreasing gradient from the highest and earliest to the lowest and latest. In the northwestern portion of this region the valley trains and terraces are very well-developed (see Plate 1).

The outwash materials are frequently covered by a sandy clay layer, "hard pan". According to the processes of sedimentation this layer was formed during the last stage of outwash; at that time the current coming from the upstream valley directly changed into streamline current of lower velocity, and the suspended clay and silt had enough time to precipitate. It is commonly present in the low relief parts of the outwash plain, and differs from typical till in (1) the content of a considerable amount of sand and gravel near the base and (2) the gradation relation with underlying sand and gravel.

The Outwash-Margin Lake Deposits and Alluvium:- The outwash margin lake deposits are closely associated with the fluvio-sediments, and are generally located along the margin of the main outwash plain. They are composed of dark, carbonaceous, parallel bedded clay and silt with fine laminations.

In this region down the main intermittent stream, the outwash valley train is flanked by fine to very fine-grained pond-water deposits. Evidently these depressions were formed by the aggradation of the outwash valley trains, which blocked the tributaries and created lakes in them. These deposits recieved contributions by lateral discharge from the valley train as well as from the present tributaries.

Recent

Alluvium

The alluvium is confined to small flood plains along both sides of the main intermittent stream and its tributaries. It consists of clay, silt and some sands with fine lamination and faint cross-bedding, which indicate these sediments were formed chiefly by the laminar flow of water. Fine-grained sand lenses occur locally.

PETROGRAPHY AND RESOURCES OF SAND AND GRAVEL

Petrography

The outwash is made of clastic detritus, and represents the typically mechanical mixtures of pebble and cobble fraction in association with fine to coarse-grained sand and some silt and clay detritus. On the basis of electric soundings, the thickness of outwash sediments ranges from 1 foot to 111 feet, and averages 30.07 feet (Table 3, Appendix).

According to the Wentworth's grade scale (Table 4), the textural properties of outwash sediments are determined by mechanical analysis. Graphic representation of size distriburion data (Tables 5 & 6) is shown by the composite histograms and cumulative curves (Figures 1-10). The histogram is a block diagram, which gives the percentage of grain weight in the grade sizes present in the sediment. From the histogram data the cumulative curve is made by adding the weight percentages in succeeding grades and drawing a smooth curve through the points. By means of the cumulative curve, the textural parameters are quantitively expressed. The quartiles are determined by following the 25 and 75 percent lines on the graph to the right until they intersect the cumulative curve, and reading the values on the size scale, which lie directly below the intersections. According to Trask (1932)[10], the sorting coefficient (SO) is defined as the square root of the ratio of the larger quartile, the 25 percent value, Q1, to the smaller quartile, the 75 percent value, Q3. The median diameter is found along the 50 percent line, and it is the average grain diameter of the sediment.

TABLE 4

WENTWORTH'S PARTICLE SIZE CLASSIFICATION

Grade Limits			
Diameter in MM		Diameter in Inches	Name
Above	256	10	Boulder
	256-128	10-5	Larger cobble
	128-64	5-2.5	Small cobble
	64-32	2.5-1.25	Very large pebble
	32-16	1.25-0.62	Large pebble
	16-8	0.62-0.31	Medium pebble
	8-4	0.31-0.15	Small pebble
	4-2	0.15-0.078	Granule
	2-1	0.078-0.039	Very coarse sand
	1-1/2	0.039-0.019	Coarse sand
	1/2-1/4	0.019-0.009	Medium sand
	1/4-1/8	0.009-0.004	Fine sand
	1/8-1/16	0.004-0.0024	Very fine sand
Below	1/16-	0.0024-	Coarse silt to fine clay

The significance of the degree of sorting is that it indicates the spread of the distribution of uniform sizes present in sediment, and directly influences the percentage of pore space in a rock. Generally the wider the spread, the poorer the sorting; poorly sorted sediments are less porous than well-sorted sediments. As to Trask (1932)[10], well-sorted sediments have values of sorting coefficient (SO) less than 2.5, moderately sorted sediments range from 2.5 to 4.0, and poorly sorted sediments have values larger than 4.0.

Samples under study show mostly well to moderately sorted values. Some are poorly sorted. This evidence indicates the current conditions in most cases are rather constant, and turbulent flows show less tendency away from the source. The median diameters range from 0.205mm to 130mm and averages 19mm. They are associated closely with the strength of current that moved the material to the site of deposition. For instance, cobbles and boulders have the values of larger median diameters and were carried much shorter distances than the sand and silt.

As a rule, changes of environment are mainly responsible for the changes of texture. The most typical contrast within these sediments, is between channel-type deposits, characterized by the deposition of cobble and pebble detritus, and the bypassing of fine detritus, characterized by the precipitation of fine-grained detritus and non-arrival of the cobble detritus.

The cobbles and pebbles are well-rounded to subrounded, and more or less segregated as to size. Accordingly, there is a progressive decline in size of the cobbles and pebbles as the rounded rock fragments are followed along the strike away from the places of maximum thickness. Concerning the main structural features, the coarse gravels are commonly intercalated with pod-like sand lenses, which are cross-bedded. Sporadic cobbles, and pebbles or pebbly laminae are not uncommon. Cut-and-fill structure, lenticular bedding, and imbrication of the flatter pebbles and cobbles are generally present. All these features are found not far away from the source, and suggest strong current action at the time of deposition.

The gross composition of rounded rock fragments, which include the diameter range from 0.20 mm to 6.60 mm is given in Table 7. The most predominant constituents are calcareous rocks and associates, averaging 42.86 percent, and crystalline rocks averaging 30.61 percent; the clastic rocks and associates are less in amount, and averaging 25.28 percent. Among them limestone, including dolomitic varities, calcic dolomite, clay ironstone, and granites are the most conspicuous rock types. The fine- to rather coarse-grained sediments consist chiefly of quartz grains. On the basis of mechanical analysis, silt and clay fraction averages 2.11 percent in weight, which tentatively shows that the plasticity index of outwash sediments is low. Probably it ranges from 0 to 6.

TABLE 5

TEXTURAL STUDY OF A SUITE OF TYPICAL GLACIAL OUTWASH SEDIMENTS

Locality	Sample No.	Mechanical Analysis* (Diameter in MM)													Total Wt. Percent	Textural Parameters			
		256-128	128-64	64-32	32-16	16-8	8-4	4-2	2-1	1 - 1/2	1/2 - 1/4	1/4 - 1/8	1/8 - 1/16	1/16–		Q1	M	Q3	SO
Sec29 T120N R74W	101		15.84	9.94	21.80	11.95	9.80	6.51	6.41	8.44	5.67	1.73	0.71	1.15	99.95	32	14	2	4.000
Sec29 T120N R74W	102	41.75	33.01	11.78	2.06	1.52	2.11	1.79	2.00	1.72	0.86	0.62	0.26	0.46	99.94	155	112	62	1.732
Sec11 T118N R74W	103		54.23	19.19	3.66	3.72	4.17	2.81	2.53	3.02	2.97	2.02	0.65	0.68	99.65	100	69	22	2.236
Sec11 T118N R74W	104	53.29	32.02	4.36	2.44	1.79	1.20	0.89	0.91	1.04	1.02	0.59	0.18	0.20	99.93	175	130	96	1.414
Sec1 T120N R74W	105		15.81	11.63	12.72	13.97	10.19	7.62	7.11	6.75	7.85	4.33	1.04	0.92	99.94	35	10	1.5	4.796
Sec36 T121N R74W	106		14.51	11.56	8.40	4.75	10.58	10.95	11.34	12.92	9.47	3.47	0.89	1.09	99.93	33	4	0.9	6.000
Sec33 T120N R74W	107	28.02	23.14	18.22	7.56	3.44	3.05	2.46	3.65	4.32	2.74	1.27	0.54	1.00	99.41	130	68	19	2.646
Sec32 T120N R74W	108		56.11	14.98	4.27	2.91	3.34	3.03	4.67	4.31	2.59	1.25	0.69	1.85	100.00	104	72	17	2.646
Sec20 T120N R74W	109		17.53	19.01	10.46	8.05	11.05	8.83	8.84	7.79	5.67	1.79	0.44	0.54	100.00	47	12	1.9	5.000
Sec11 T118N R74W	110			3.63	2.99	3.02	3.11	4.00	7.71	14.71	21.85	22.59	9.13	7.19	99.93	092	0.32	0.19	2.236
Sec5 NW T120N R74W	111					3.97	12.60	12.09	18.26	20.42	16.66	9.90	3.05	3.00	99.95	2.5	0.9	0.37	2.646
Sec5 NW T120N R74W	112					6.69	8.79	15.47	22.47	22.70	14.88	6.92	1.09	0.94	99.95	1.8	1.08	0.52	1.732
Sec5 NW T120N R74W	113				0.37	0.41	0.69	1.28	4.42	21.16	52.00	14.02	0.75	4.84	99.94	0.52	0.40	0.28	1.414
Sec33 T120N R74W	114					7.09	6.28	9.73	14.02	19.78	23.79	15.10	2.66	1.55	100.00	1.80	0.65	0.31	2.449
Sec33 T120N R74W	115					5.40	5.10	7.90	17.54	34.78	23.59	4.37	0.69	0.59	99.96	1.50	0.78	0.45	1.732

* Wentworth's grade limits   Q1 1st Quartile   Q3 3rd Quartile   M Median   SO Sorting Coefficient

TABLE 6

TEXTURAL STUDY OF GLACIAL OUTWASH SEDIMENTS FROM THE CITY PARK, LEBANON

Sample No.	Depth (Feet)	Mechanical Analysis* (Diameter in MM)										Total Weight Percentage	Textural Parameters			
		32-16	16-8	8-4	4-2	2-1	1 - 1/2	1/2 - 1/4	1/4 - 1/8	1/8 - 1/16	1/16-		Q1	M	Q3	SO
1001	3- 4					16.29	19.84	31.82	21.61	5.38	5.03	99.97	0.72	0.36	0.23	1.732
1002	4- 5				2.30	1.95	9.64	43.18	35.06	5.66	2.17	99.96	0.40	0.27	0.19	1.414
1003	5- 7				8.53	3.19	6.12	22.83	45.20	10.13	3.69	99.69	0.39	0.205	0.14	1.732
1004	7- 8	1.65	5.68	11.49	12.90	11.15	12.88	19.82	17.85	4.91	1.62	99.95	2.90	0.68	0.25	3.464
1005	8- 9		2.10	4.42	8.99	10.77	21.15	27.00	19.64	3.96	1.92	99.95	1.10	0.45	0.25	2.000
1006	9-10		5.97	9.91	8.47	11.13	18.91	27.76	13.10	2.27	2.39	99.91	1.90	0.58	0.28	2.646
1007	10-11		5.99	5.97	6.72	10.63	19.32	26.28	17.26	3.66	4.12	99.95	1.30	0.48	0.25	2.236
1008	11-12	3.49	0.36	5.46	7.71	10.02	17.28	28.50	22.08	3.68	1.36	99.94	1.15	0.42	0.24	2.236
1009	12-14		0.26	1.03	2.39	7.47	18.00	29.25	30.22	7.99	2.85	99.46	0.78	0.29	0.175	2.000
1010	14-15	8.00	2.80	4.60	6.20	8.00	13.50	28.33	21.52	4.22	2.18	99.35	1.50	0.41	0.230	2.646
1011	15-17	8.13	3.40	3.04	3.38	5.28	12.16	27.17	27.38	7.39	2.53	99.86	0.90	0.32	0.19	2.236

* Wentworth's grade limits   Q1 1st Quartile   Q3 3rd Quartile   M Median   SO Sorting Coefficient

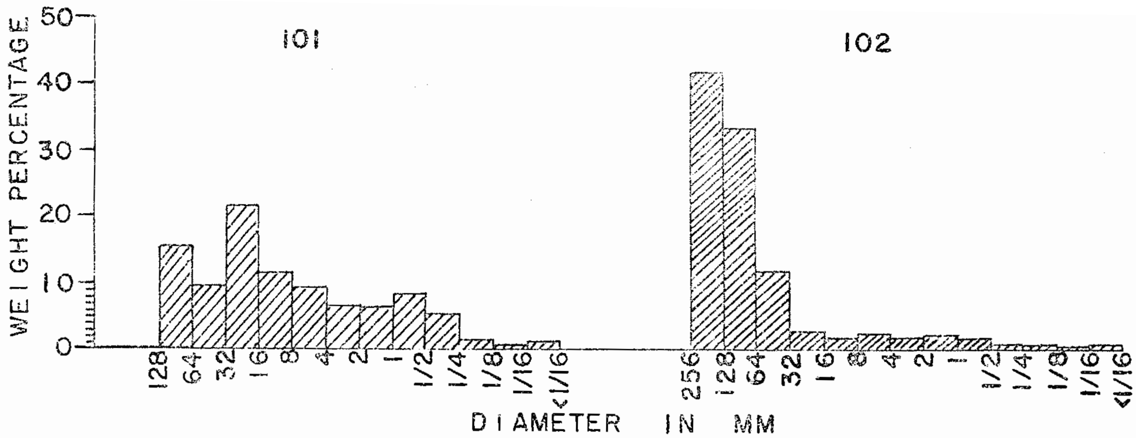

FIG. 1 HISTOGRAMS SHOWING GRAIN-SIZE DISTRIBUTIONS IN TWO SAMPLES. 101, NW1/4 SEC.29 T120N R74W. 102, NE 1/4 SEC.29 T120N R 74 W. (Data based on TABLE 5)

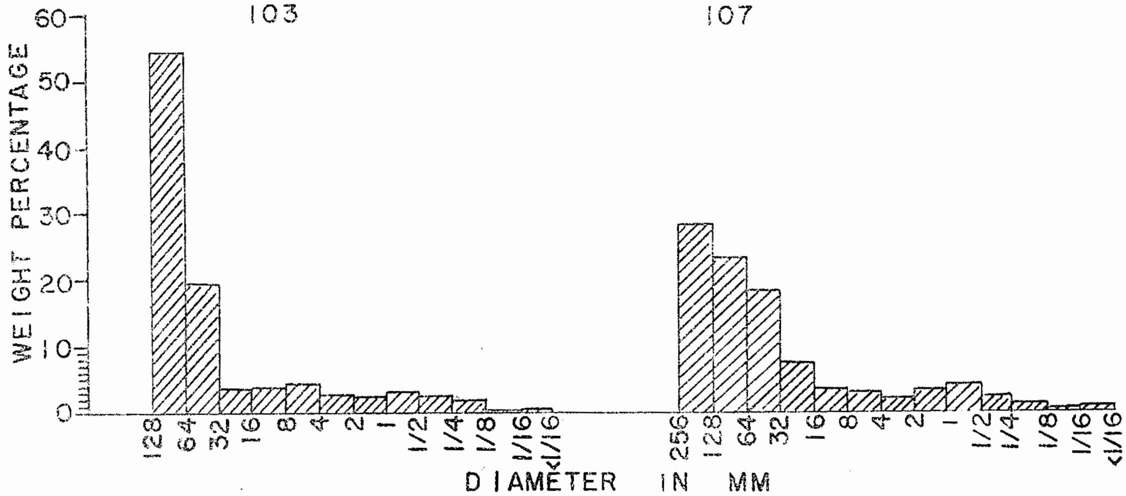

FIG. 2 HISTOGRAMS SHOWING GRAIN-SIZE DISTRIBUTIONS IN TWO SAMPLES. 103, SE 1/4 SEC.11 T118N R 74 W
107, NW1/4 SEC.33 T120N R 74 W
(Data based on TABLE 5)

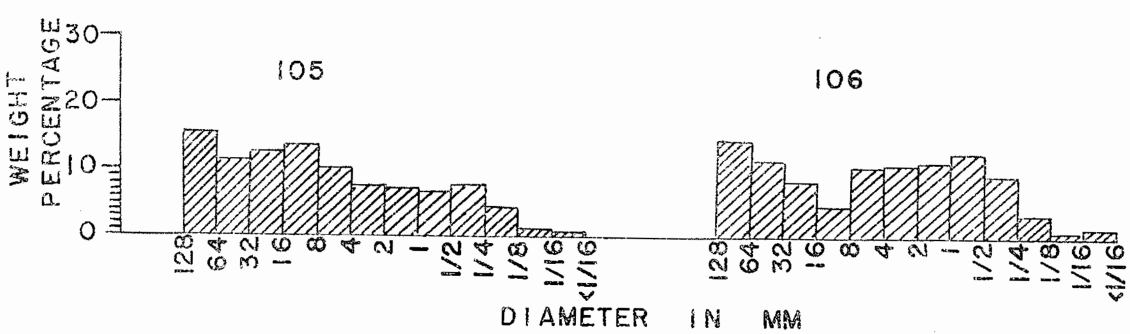

FIG. 3 HISTOGRAMS SHOWING GRAIN-SIZE DISTRIBUTIONS IN TWO SAMPLES. 105, NE1/4 SEC.1 T120N R 74 W
106, SE1/4 SEC.36 T121N R 74 W
(Data based on TABLE 5)

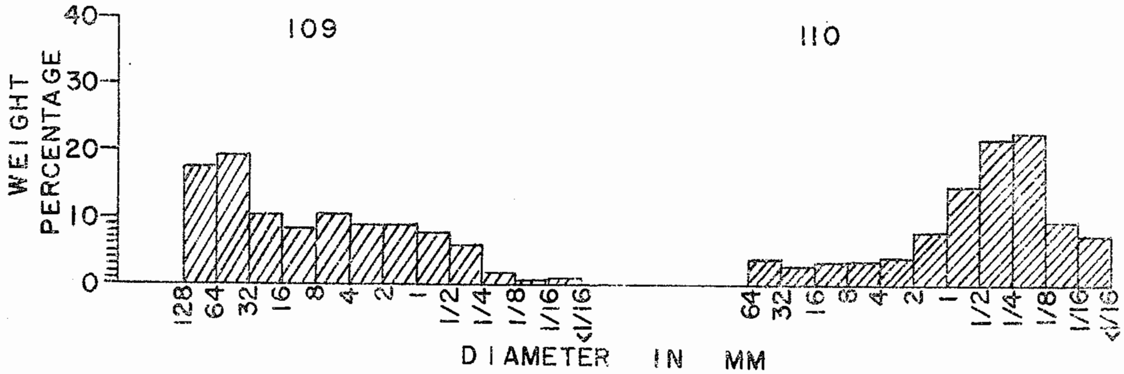

FIG. 4 HISTOGRAMS SHOWING GRAIN-SIZE DISTRIBUTIONS IN TWO SAMPLES. 109, NW 1/4 SEC. 20 T120N R74W
110, SE 1/4 SEC. 11 T118N R74W
(Data based on TABLE 5)

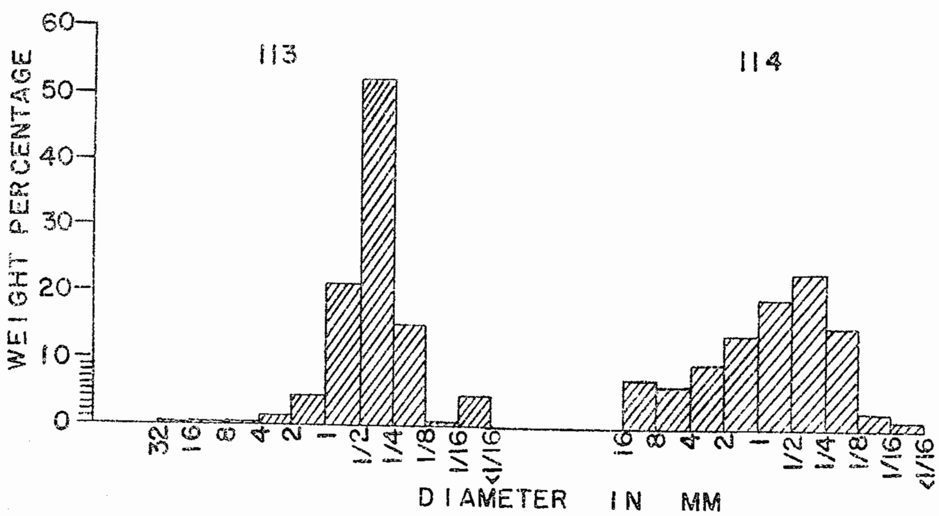

FIG. 5 HISTOGRAMS SHOWING GRAIN-SIZE DISTRIBUTIONS IN TWO SAMPLES. 113, H. ABLER'S WELL, NW 1/4 SEC. 5 T120N R74W
114, NW 1/4 SEC. 33 T120N R74W
(Data based on TABLE 5)

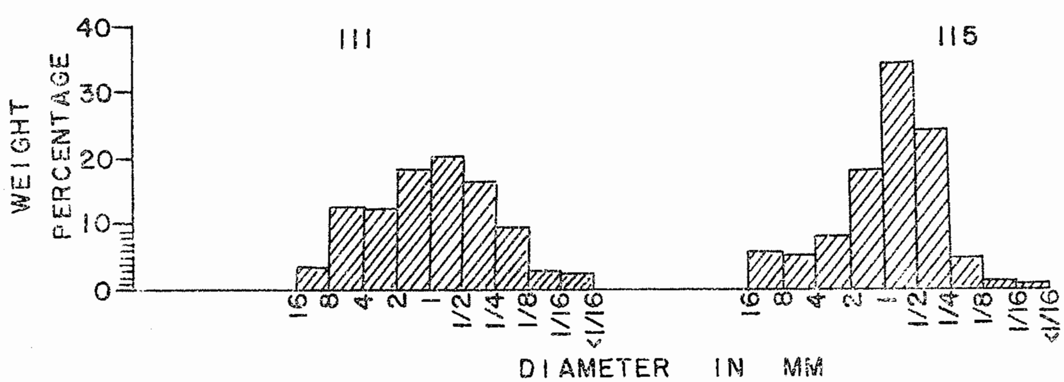

FIG. 6 HISTOGRAMS SHOWING GRAIN-SIZE DISTRIBUTIONS IN TWO SAMPLES. 111, H. ABLER'S WELL, NW 1/4 SEC. 5 T120N R74W
115, NW 1/4 SEC. 33 T120N R74W
(Data based on TABLE 5)

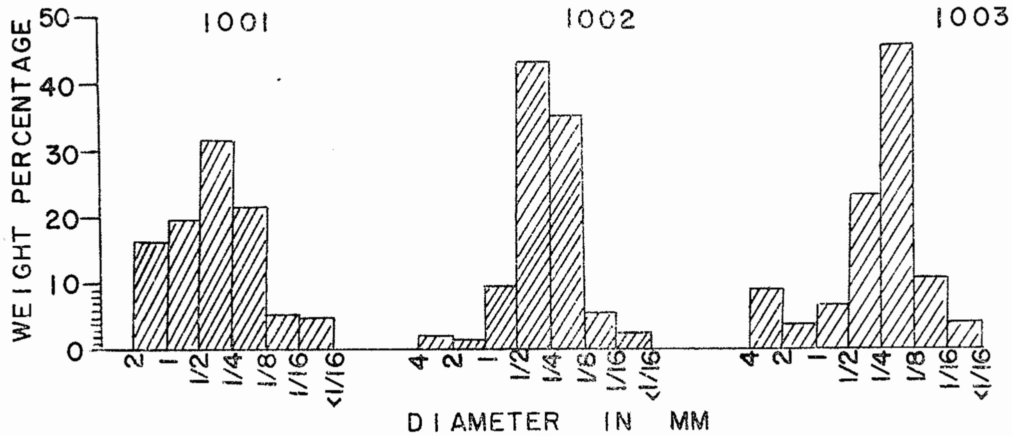

FIG. 7 HISTOGRAMS SHOWING GRAIN-SIZE DISTRIBUTIONS IN THREE SAMPLES COLLECTED FROM THE CITY PARK WELL, LEBANON

(Data based on TABLE 6)

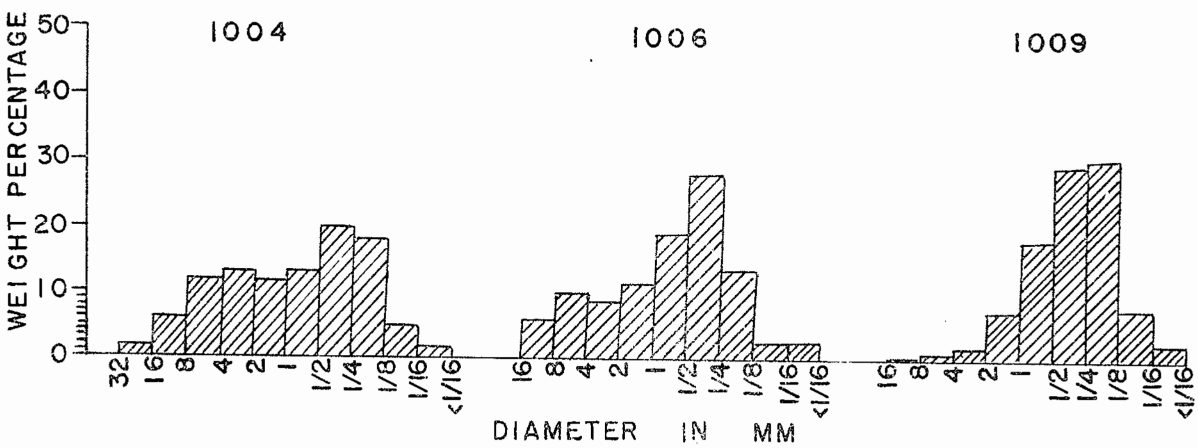

FIG. 8 HISTOGRAMS SHOWING GRAIN-SIZE DISTRIBUTIONS IN THREE SAMPLES COLLECTED FROM THE CITY PARK WELL, LEBANON

(Data based on TABLE 6)

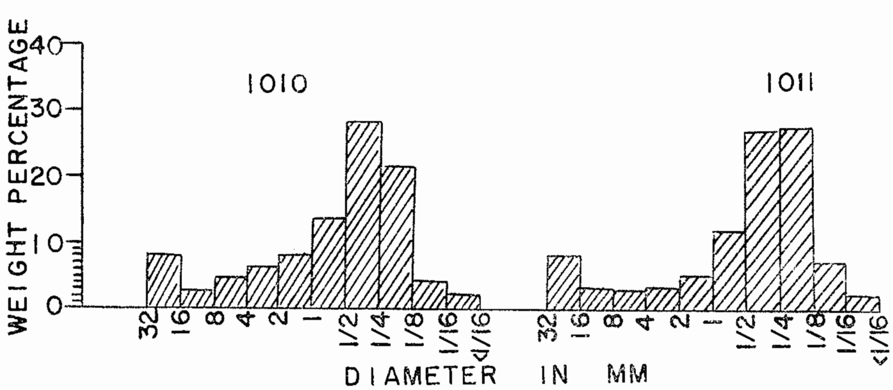

FIG. 9 HISTOGRAMS SHOWING GRAIN-SIZE DISTRIBUTIONS IN TWO SAMPLES COLLECTED FROM THE CITY PARK WELL, LEBANON

(Data based on TABLE 6)

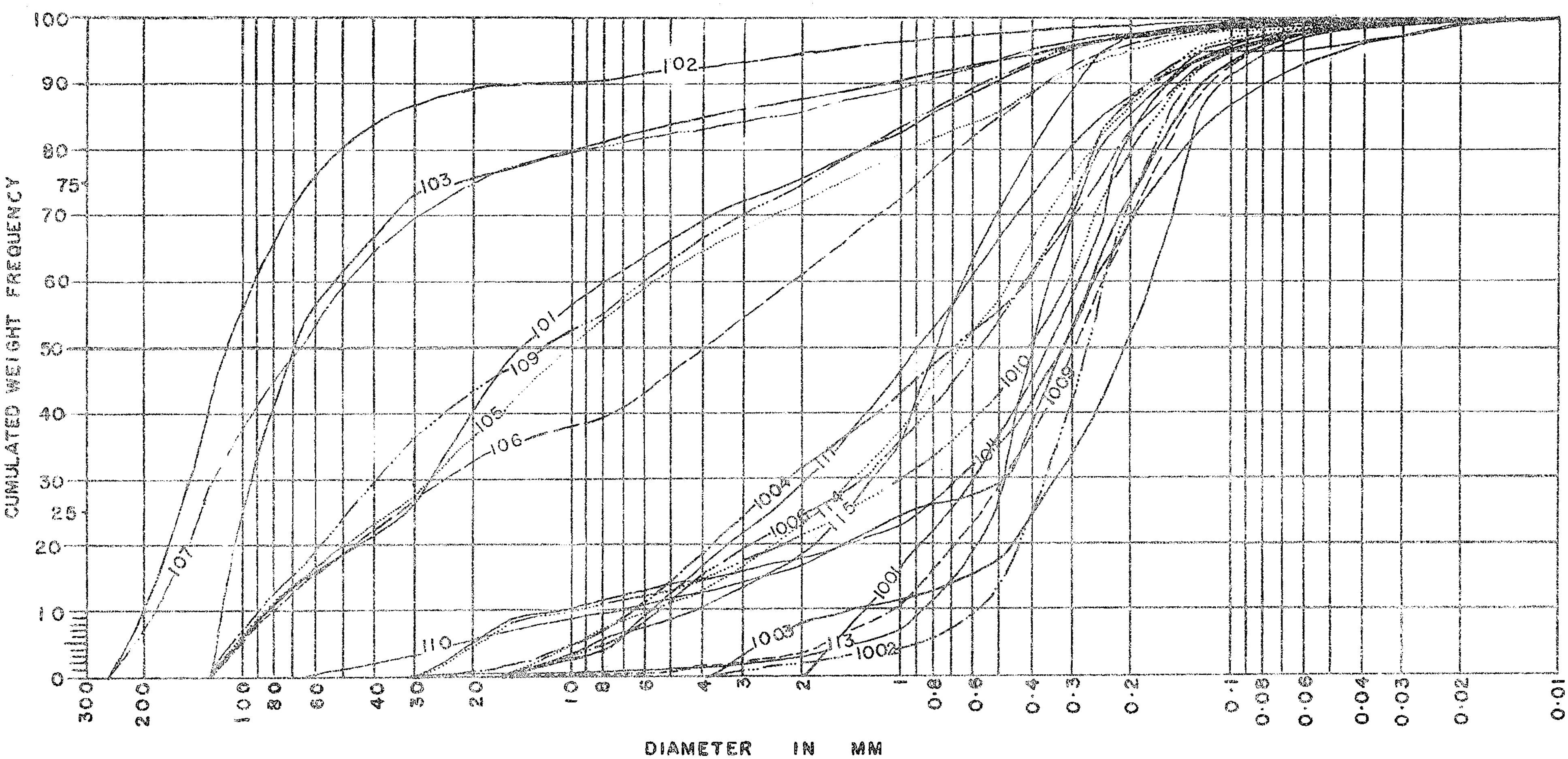

FIG. 10 CUMULATIVE CURVES SHOWING GRAIN-SIZE FREQUENCIES OF THE SAME SEDIMENTS PRESENTED AS HISTOGRAMS IN FIGURES 1-9

TABLE 7

LITHOLOGIC COMPOSITION OF THE GRAVEL
(PERCENT IN NUMBER)

Rock Type \ Sample No. / Location	101 Sec29 T120N R74W	102 Sec29 T120N R74W	103 Sec11 T118N R74W	104 Sec11 T118N R74W	105 Sec1 T120N R74W	106 Sec6 T121N R74W	107 Sec33 T120N R74W	108 Sec32 T120N R74W	109 Sec20 T120N R74W	Dia. Range (inches)
Dolomite:										
Gray								0.84	0.22	0.90-5.70
Brown							0.37			1.35
Gray (Calcic)	2.18	3.82	7.25	17.07	5.03	24.00	12.63	8.01	5.28	0.20-4.10
Limestone:										
Light gray	30.60	31.48	19.50	15.60	43.95	19.00	14.12	14.76	20.70	0.40-6.60
Dark (Black)		0.42			0.33				0.88	1.60-3.20
Gray (Dolomitic)	6.01	5.95	17.65	7.80	5.03	2.00	10.03	18.52	4.62	0.25-2.80
Chert:	1.91		0.63	0.97	1.00	3.00	0.74	0.42	0.44	0.42-1.20
Calcareous rocks & associates:	40.70	41.69	45.03	41.44	55.34	49.00	37.84	42.55	32.14	
Sandstone:										
Gray		6.38				1.00	NC1.11	NC0.84	C 0.22	0.25-1.90
Brown	0.54			C 0.48			C0.37		NC0.44	0.70-1.85
Shale:	C 13.66			NC1.95		NC			NC	
Black	NC 4.09		NC2.20	C 0.48	C3.35	10.00	NC7.43	NC1.68	35.24	0.25-2.50
Other				NC0.48	NC1.67		C 0.37			0.50-1.80
Clay ironstone:	12.84	9.78	16.71	23.41	12.99	8.00	19.33	21.51	9.03	0.40-3.25
Clastic rocks & associates:	31.13	16.16	18.91	26.80	18.01	19.00	28.61	24.03	44.93	
Igneous:										
Granite	16.11	20.84	17.66	19.99	14.08	24.00	15.97	10.12	12.98	0.30-6.00
Dioritic	1.63	2.12	1.26	1.46	1.34	1.00	0.74	5.89	0.22	0.35-3.10
Basaltic	1.91	4.25	6.90	5.36	2.66		3.71	2.95	3.30	0.45-4.10
Metamorphic:										
Quartzite	2.18	2.12	2.20	1.46	1.00	1.00	1.48	1.26	0.88	0.30-3.70
Slate (Argillite)	3.82	1.70	2.50	1.95	4.36	2.00	4.83	0.42	3.74	0.50-1.90
Schist	0.81	9.78	3.47	0.48	1.34	3.00	2.23	2.53	1.54	0.40-2.80
Gneiss	1.36	0.85	1.57	0.97	1.00		4.46	2.53	0.22	0.70-3.75
Crystalline rocks:	27.82	41.66	35.56	31.67	25.78	31.00	33.42	25.70	22.88	
Total Percentage:	99.65	99.51	99.51	99.91	99.13	99.00	99.92	92.28	99.95	

C Calcareous NC Noncalcareous

Resources

The estimates of the resources of sand and gravel are computed by sections into volume of cubic yards. The average thickness of sand and gravel is obtained from the Table 3 (Appendix), and topographic factor is taken into consideration. The total estimated volume is 883,126,432 cubic yards. Two thirds of this amount is calculated from Hoven Outwash. According to the textural study, the plasticity index of sand and gravel is low, therefore, these materials are very good for use in highway paving and concrete aggregate.

SHALLOW WATER

GENERAL SETTING

Generally speaking, the amount, capacity and movement of ground water chiefly depends on the mean values of annual precipitation, the character of the rocks, and the surface of the land forms. In this region the Wisconsin drift, especially the sand and gravel portion, is considered as a good place for shallow water storage, and water can move through the mass without much difficulties. Hence, these sediments furnish the main water supply to shallow wells. The Pierre shale consists of very fine to fine-grained silt and clay, and is very impermeable; it is not taken into further consideration here.

SOURCE

Groundwater is furnished almost entirely from precipitation in the form of rain or snow in this region. Part of the water is carried away by surface run off, and eventually is lost to streams, part of it may evaporate or be absorbed by vegetation and transpired into the atmosphere. The part that escapes surface run off, evaporation and transpiration, percolates downward through the top soil and underlying strata until it reaches the water table where it joins the body of ground water in the zone of saturation.

The mantle rocks present in this region consist of the unconsolidated Wisconsin drift. This drift consists of clastic sediments ranging from cobbles to clay, the clay being the minor constituent. The soil derived from these underlying strata is mostly silty and sandy. These materials easily facilitate the percolation of water, in other words, the amount of precipitation reaching the ground water body is probably nearly 100 percent of the total rainfall.

OCCURRENCE

In this region, the occurrence of shallow water is controlled by the physical characters, structure and distribution of the Wisconsin drift. As already stated, the drift consists of till and stratified sediments. The chief constituents of till are "boulder clay" with silt and clay-rich matrix. Because the till, is an unassorted mixture and contains particles of great variety in size, it has a very low porosity. The stratified drift is made up mainly of sand and gravel, which had been examined through 26 samples, and have the value of average sorting coefficient, 2.193 (Tables 5 & 6); this figure indicates these sediments are well-sorted, and have rather higher porosity.

The porosity is the percentage of the voids or interstices in the rock. It is a function of the uniformity of particle size and shape and of the state of packing of the particles. The higher degree of the uniformity of particle size is present in the well-sorted sediments. In other words, poorly sorted sediments are generally less porous than well-sorted sediments.

In addition to porosity the amount of ground water, which can move through it toward a pumping well is directly influenced by the permeability of the rock, which controls the relative ease of flow of fluids. The permeability is determined by size, shape and arrangement of the openings. Coarse gravel has large openings among the pebbles, affording easy passage for fluids. As the particles become smaller, the pores also become smaller. Molecular attraction holds a very fine layer of water on the surface of each grain which might almost fill all the openings in such a fine-textured sediment. Thus a greater force or a greater length of time is required to drive a unit volume of fluid through the sediment. In other words, the water-yielding capacity of the rock is very low even though its porosity is very high. Generally water moves most freely through a rock that has relatively large and well-connected openings.

THE WATER TABLE AND MOVEMENT OF SUBSURFACE WATER

General Setting

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)[5]. It can also be regarded as the boundary between the zone of saturation and the zone of aeration (Fig. 11). The irregularities of the water table and nature of movement of water are controlled by the differences in permeability or thickness of the water-bearing materials, unequal addition to or withdrawls from the ground water reservoir at different places, topography and the structure of rocks.

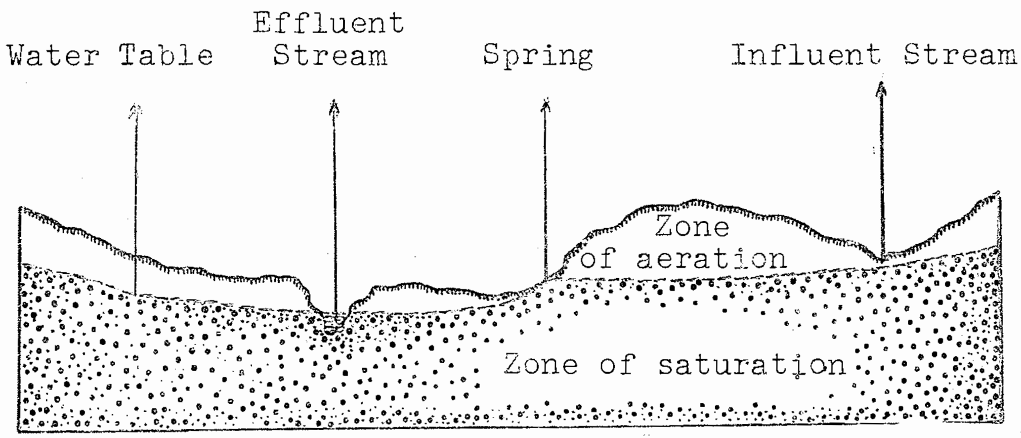

Fig. 11 Cross section showing the water table and its relationship to streams and springs.

Shape and Slope of the Water Table With Relation to Topography

The water table is not a level surface but rather is generally a sloping surface. The shape of the water table commonly conforms the regional topography. It slopes upward under the major divide areas to a crest about midway between the major streams, but is at a greater depth under the divide areas than it is under the valley bottoms. Thus, a well drilled in a valley will generally encounter water at a shallower depth than a well drilled on a nearby divide.

In this region the seven pre-moraine valley-channels were filled with sand and gravel. The main bodies of shallow water flow down along these configurations. As a rule, the velocity of the shallow water movement depends on the permeability of the sediments, the hydraulic gradient, and the shape of the water table. The direction of movement of the main shallow water bodies in the Blue Blanket and Hoven Outwashes, therefore, is from the east toward the northwest, and makes an oblique angle with the surface flow in the present major intermittent stream on the west side of these reservoirs. In the vicinity of Hoven, minor topographic features cause some variation in direction of shallow water flow. This fact indicates the gradient of the water table has a considerable variation in shape. During the investigation the major stream on the west was dry. This shows the stream bed is above the water table, and loses water by seepage rather than gains it. This kind of stream is called "influent" rather than "effluent" -- (See Fig. 11).

Fluctuation of the Water Table

The rise of the water table is controlled by the amount of rainfall that descends through the soil to the water table, the amount of water entering the main shallow water body from the surrounding Wisconsin till, and a little seepage that reaches the underground reservoir from surface flow in the intermittent stream whose channel is usually above the water table. The decline of the water table is directly influenced by the amount of water pumped from wells, the amount of water absorbed directly from the water table for transpiration through plants.

Because of the rapid annual changes of climate in this region, the fluctuation of the water table is great. During the wet months the water table may rise considerably and during the dry months it will gradually decline. If the inflow to the underground reservoir exceeds the draft, the water table will rise; conversely, if the draft exceeds the inflow, the water table will decline. Thus, the rate and magnitude of fluctuations of the water table depend upon the rate and magnitude at which the underground reservoir is replenished or depleted.

RECHARGE

Recharge is the addition of water to the underground shallow water reservoir, and is accomplished from local precipitation, ponds or swamps, and subsurface inflow.

Recharge from Local Precipitation

According to the climate data issued by the U. S. Weather Bureau, the annual average precipitation is 17.76 inches from 1931 to 1954 in this region. According to Fox (1949)[2], "1 inch of rainfall on 1 square mile of land surface is equivalent to 2,323,000 cubic feet of water", or more than 50 acre-feet*. Thus the 17.76 inches would be 888 acre-feet of water per square mile.

Generally speaking, the amount and frequency of recharge depend on the depth to the water table and the type of material occurring above the water table. During the investigation the depth of the water table ranged from 6 to 65 feet (See Table 8, Appendix). As has been stated, the mantle rocks which act as

*: One acre-foot is equivalent to 43,560 cubic feet.

chief transmitting agent in recharge in this region are typically clastic sediments. A considerable amount of precipitation therefore could enter the zone of saturation without much difficulty. Once the water becomes a part of the groundwater body, it moves down the slope of the water table, later to be discharged for the most part into the channels of the subsurface streams.

Recharge From Ponds or Swamps

Ponds or swamps are scattered through this region, especially along the front of the Lebanon end moraine. They furnish a considerable amount of water for the recharge of the shallow water reservoir. At the time of this investigation most of these ponds were dry. One of them, situated in Section 22, T.119N, R74W, and the other located in Sections 22, 15, 16 and 21, T119N, R74W, were dry for the first time in the past 15 years. Evidently the water partly percolated downward to the shallow water body, and was partly lost by evaporation. Two dam sites and some large depressions occurring in the northwestern portion of this region are constantly furnishing water to the shallow water body.

Recharge From Subsurface Inflow

The subsurface inflow, which furnishes water to the shallow water body, is entirely derived from the Wisconsin till. Both of the Cary and Iowan till yield abundant supplies of water, and also act as a transmitting medium in upland areas. Several domestic 2-foot wells, which are recorded on Table 8 (Appendix), and represented by the Simon's well in Section 8, T118N, R74W, the Schmacher's well in Section 4, T119N, R74W, and the Hageman's well in Section 3, T120N, R74W, penetrated the till. The depth of water in them ranged from 10 feet to 52 feet. The average depth of water is 30 feet. This figure is very seldom found in the wells, which were dug through the outwash sands and gravels. Apparently this water furnishes the main recharge to the shallow water body.

DISCHARGE

Discharge is the loss of water from the shallow water reservoir. It may be lost by the natural discharge at the surface and by pumping from wells.

Natural Discharge at the Surface

The greater part of the discharge is accomplished by shallow water movement into the main stream channels, and some part at the surface may evaporate or be absorbed by vegetation and transpired into the atmosphere. Under this condition a state of approximate equilibrium might exist, that is the average annual recharge could be balanced by an approximately equal average annual discharge. There is no record of such an equilibrium in this region, however. Seepages most likely account for the major part of the shallow water discharge.

Discharge From Wells

Wells constitute one of the principal means of discharge of shallow water. All domestic supplies have been obtained from the shallow wells, but the total quantity of water pumped annually from wells is not known. A statistic account from the city well at Hoven shows the average monthly discharge is 2,075,713 gallons. Most of the residents in this region obtain their domestic and stock supplies from the shallow wells, but the total volume of water pumped for such uses is probably less than that used by the city.

RECOVERY

Principles of Recovery

Recovery is a process of recharge after the well is pumped. When water is withdrawn from a well, there is a difference in head between the water inside the well and the water in the surrounding material for some distance from the well. The water in the vicinity of the well develops a cone of depression (Fig. 12). Generally a higher pumping rate produces a greater drawdown, and the diameters of the cone of influence and of the area of influence will be greater. The rate of yield per unit of drawdown is called the specific capacity of a well, and it is commonly stated in gallons a minute per foot of drawdown after a specified period of pumping. When a well is pumped the water level drops rapidly at first and then more slowly and it may continue to decline until a balance is reached between recharge and pumping. It is generally important to continue pumping until the water level remains approximately stationary.

The character and thickness of the water-bearing materials have a definite influence on the yield and drawdown of a well. If the water-bearing material is coarse and of fairly uniform size it will readily yield large quantities of water to a well with a minimum drawdown; if the water-bearing material is fine or poorly sorted it will offer more resistance to the flow of water, thereby decreasing the yield and increasing the drawdown. Thus the drawdown of a well varies inversely with the permeability of the water-bearing material.

Wells, which penetrated the outwash mass, have comparatively rapid yield and slow drawdown, because the outwash sediments are generally fairly well sorted. The city well at Lebanon was dug into well sorted sand and gravel, and has a larger specific capacity and rapid yield due to the higher percentage of porosity and the good permeability. The permeability generally increases toward the source area. Several wells dug in the vicinity of ice-contact sediments, have a rapid recovery during certain time of pumping. Koehn's well in Section 4, T119N, R74W, is an example; after being pumped a short time, the recovery preceded rapidly, and the water level was easy to maintain approximately stationary.

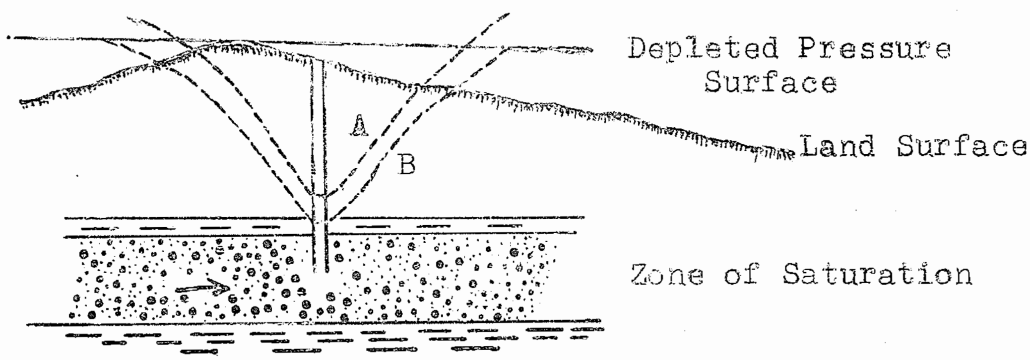

Fig. 12 Depleted pressure surface produced by overpumping. A, Cone of pressure relief at start of pumping; B, Cone produced by pumping in excess of replenishment. (After Tolman, 1937, p. 327)[9].

Types of Wells

In this region water wells were mostly dug by drilling auger, some of them were dug by hand auger, and a very few of them were drilled by professional drillers. The depth of wells ranges from 6 feet to 110 feet, and average depth is 37 feet. Their locations and descriptions are shown on Plate 2, and Table 8 (Appendix).

Methods of Lift and Types of Pumps

Water from many of the domestic wells is obtained by wind-mill operated lift. Pitcher pumps are used on some dug wells, and a few number of pitcher pumps are hand operated. Jet pumps and horizontal centrifugal type of lift are used by some of the farmers. Turbine pump is used by the city of Hoven on No. 1 & 2 wells. Some of the domestic wells are powered by electric motors, and stationary gasoline engines. Only Rausch's family uses a tractor engine in his private irrigation.

UTILIZATION

More than a hundred domestic shallow wells and four public wells were investigated in this region. The discussion on their utilization will be divided into 1) domestic and stock supplies, and 2) public supplies.

Domestic and Stock Supplies

The domestic wells are located by the house or in the basement. Most of the families have two or more wells for domestic uses. Wells for stock are situated near the barn or in the pasture, and they are the main source for stock water. The chief domestic uses are including drinking, cooking, washing and in some cases the disposal of sewage, for instance, in the city of Lebanon.

Public Supplies

The public water wells are located in the cities, Hoven and Lebanon. There are two public wells in the city of Hoven. Number one is abandoned while number two furnishes the water supplies for the residents of Hoven. Each month the approximate water pumpage is around 2,075,713 gallons, part of which is used for the disposal of public sewage. Two good wells were dug in the city park of Lebanon. The only use is to provide water for the swimming pool during the summer season.

QUALITY OF WATER IN THE VICINITY OF HOVEN

This discussion is based on the water analyses of the city wells, Hoven (Table 9). The quality of water is very important in determining its suitability for sanitary purposes, drinking, domestic use, and the safe use in boilers for making steam. All these purposes should be carried out on the basis of chemical analyses of water. Although the taste may furnish valuable evidence as to the nature of water; good drinking water should be tasteless, and fresh waters which taste flat are unattractive. In determining the quality of water, the important things are the purity, acidity, and alkalinity. Alkalinity is due to the presence of dissolved carbonates of the alkaline earth metals, and acidity is due to the presence of organic acids. The alkaline waters carry the chief compounds for the determination of "Hardness". There are two kinds of hardness; temporary hardness and permanent hardness respectively. Temporary hardness is usually due to the presence of the bicarbonate of calcium and magnesium; it is also known as "Carbonate hardness". This hardness can be partially removed by boiling, and completely eradicated by a judicious addition of lime.

TABLE 9

WATER ANALYSES* OF THE CITY WELLS, HOVEN

Contents	No. 1 Well	No. 2 Well
	Parts per Million	
Total Solids	682.00	693.00
Na (Alkali)	54.68	36.98
Ca (Calcium)	109.80	131.50
Mg (Magnesium)	26.29	29.53
Mn (Manganese)	0.46	0.80
N (Nitrate)	2.00	3.50
F (Fluoride)	0.25	0.37
Cl (Chloride)	14.00	38.00
SO4 (Sulfate)	212.30	213.80
HCO3 (Bicarbonate)	287.90	295.20
R2O3	1.60	3.20
Hardness (CaCO3)	382.30	451.40

* By O. D. Dunbar, State Chemical Laboratory, South Dakota
R2O3: No. 1, Fe2O3/-Al2O3/-Mn2O3
No. 2, Fe2O3/-Al2O3

To the presence of sulphates of calcium and magnesium is ascribed the permanent hardness of the water; also called as "Noncarbonate hardness". This hardness cannot be removed by boiling, and is best counteracted by the use of quicklime, or of barium carbonate and barium oxide. There is no difference between the effect of carbonate and noncarbonate hardness on soap.

Water analyses of the city wells, Hoven, show that the principal contents of the city water are bicarbonate, sulfate and calcium. Alkali, chloride, nitrate, fluoride, magnesium and manganese are subordinate in amount. The compounds of calcium, sulfate and magnesium cause the hardness of this water. On the basis of calcium carbonate content, hardness of number one well is 382.30 parts per million and 451 parts per million from number two well. Generally speaking water containing less than 500 parts per million of dissolved solids is entirely satisfactory for domestic use. Fox mentioned (1949) that if a water contains 50 to 100 parts of CaCO3 (Calcium carbonate) in solution it is a "Soft water"; with 100 to 200 parts of CaCO3 it is a "Medium hard water"; and with 200 to 300 parts of CaCO3 it is a "Hard water". According to this classification, the city of Hoven is "Very hard" in quality. Very hard water is found to be disagreeable for washing purposes; very soft water, on the other hand, although excellent, does not prove agreeable as drinking water; the best drinking water is one which is faintly alkaline and slightly hard, due to the presence of a small amount of bicarbonate of calcium.

The iron (Fe) content is 0.2 part per million. The hydrogen ion concentration (pH) is 7.3 in the well number two, which indicates the acidity of this water is in normal condition. The presence of chlorine is usually an indication of sewage contamination. The presence of nitrate leads to a suspicion of organic pollution. The presence of a small amount of manganese may cause the black water problem as the staining of plumbing fixtures and clothing washed in the water.

QUALITY OF WATER IN RELATION TO STRATIGRAPHY

The changes in quality of water are directly influenced by the nature of rocks in which it occurs or through which it has passed. In this region the Wisconsin drift contributes a great amount of compounds to the composition of shallow water. Among these glacial sediments, till has been playing a major role with this action. Till is composed of unassorted mixture of the sedimentary, igneous, and metamorphic rock types, in which sedimentary rocks are very predominant, making up to 68.14

percent of the till. The carbonates of lime and magnesia are chiefly furnished by the limestone and calcic dolomite. Sulfate, manganese, and fluoride may be mostly contributed by igneous and metamorphic rocks. The Pierre shale may furnish some magnesium, chloride, and iron hydroxides.

ESTIMATES OF WATER STORAGE CAPACITY

Estimates of the storage capacity of shallow water reservoirs are based on the textural properties of outwash sediments (Tables 5 & 6 and Fig. 10). Among the textural properties, sorting coefficient (SO) directly influences the porosity, because the degree of sorting is a fundamental function of the porosity of a deposit. Generally a deposit containing a high degree of sorting has a rather higher porosity. Porosity differs greatly with changes in size, shape, and degree of interconnection of the interstices between mineral particles or rock fragments; thus, porosity is assumed on the regional basis. Lee and Ellis (1919)[3] stated that coarse sand contains 39-41 percent of voids; medium sand has a value of porosity ranging from 41 to 48 percent; fine sand contains 44-49 percent of voids. Porosity of outwash sediments is assumed as 45 percent in Sections 4, 5 and half of Section 3, T118N, R74W; in Sections 32, 33, 29, 28, 20, 21, 17, 8 and 5, T119N, R74W; and in Sections 5, 8 and 17, T120N, R74W. The reserve of sand and gravel in these areas is 4,095,699,552 cubic feet, and water storage capacity would be 1,843,064,798 cubic feet. The assumed value of porosity is 35 per cent in Section 4, T119N, R74W; in Sections 32,33,28,21,16,9 and 4, T120N, R74W. The estimated volume of sand and gravel is 9,026,903,952 cubic feet, and the storage capacity is computed to be 3,159,416,383 cubic feet. The value of the porosity is assumed as 32 percent in Sections 11, 2 and half of Section 3, T118N, R74W; in Sections 34 and 35 T119N, R74W. Total estimated reserve of sand and gravel is 2,042,789,760 cubic feet, and the storage space for water would be 653,692,722 cubic feet. Assumed porosity in Sections 29, 20, 19, 24, 18, 13, 7, 12, 1 and 6, T120N, R74W, is 30 percent. Reserve of sand and gravel is calculated in the amount of 2,792,892,960 cubic feet, and the storage space for water would be 837,867,888 cubic feet. Porosity is assumed as 27 per cent in Sections 27, 22, 16 and 9, T119N, R74W. Volume of sand and gravel is estimated as 1,491,842,880 cubic feet, and the capacity for water storage is 402,797,577 cubic feet. Near the vicinity of ice-contact sediments, porosity is assumed to be 25 percent in Section 12, T118N, R74W; in Sections 34, 27, 22, 15 and 3, T120N, R74W. The estimated reserve of sand and gravel is computed as 3,804,818,616 cubic feet, and the storage space for water would be 951,204,654 cubic feet.

The total water storage capacity in the outwash sediments is 7,848,044,022 cubic feet, or 180,166 acre-feet. During the summer season of 1955, the average depth of water was 10 feet. If porosity averages 34 percent, a vertical column a square foot in area would contain around 3.2 cubic feet of water. The mass of sand and gravel covers approximately 81,861 acres or 3,565,865,160 square feet in this reservoir. If the porosity averages 34 percent, and the vertical column of 3,565,865,160 square feet is filled with 10 feet water, the volume of water stored would be 1,212,394,154 cubic feet. This figure, however, is over one sixth of the total water storage capacity of the reservoir.

SUGGESTIONS FOR THE FUTURE DEVELOPMENT OF IRRIGATION

Seventy-five locations of shallow wells (Plate 2) are suggested for the future development of irrigation; in connection with this development, there are several important items discussed:-

Depth of Wells

Depth of suggested shallow wells range from 20 to 120 feet. In order to keep enough water in the well, each well should be stopped in the till sediments or on the top of the Pierre shale. The maximum depth will be in Sections 28, and 4, T120N, R74W, near the resistivity stations 85 and 113, where wells will encounter thicknesses of sand and gravel up to 111 feet; the minimum depth will occur along the margin of outwash sediments, and in the vicinity of outwash-margin lake deposits. As a rule, a great amount of water can be storaged in the lower portion of the outwash mass due to the high porosity of sand and gravel; water occurring in the vicinity of ice-contact sediments is generally easy to lose due to the high permeability of coarse sand and gravel, which can afford easy passage for fluids. However, some very fine to fine sediments are usually intercalated with the coarse sand and gravel which can store a considerable amount of water for the recharge to the wells.

Character of Soil

The topsoil commonly has very light to medium texture, and is silty and sandy in composition. Sandy soil is usually present on the surface of main outwash plain; surface water can rapidly percolate downward without much difficulty, therefore, the future development of irrigation should be carried out by sprinkling systems.

Quality of Water

Although water occurring in the outwash mass is suitable for irrigation, chemical analysis of water should be carried out during the period of irrigation. If water contains any boron compound in concentrations of less than 0.33 ppm, it is excellent to good for irrigation (Magistad and Christiansen, 1944)[4]. An increase in mineralization of the shallow water will probably accompany irrigation as a result of evapotranspiration and recirculation during the summer seasons. This phenomenon should be regarded as a precursor of an excessive concentration of salts in the soil and the necessary measures taken to counteract it.

SUMMARY

The Cary outwash plays a major role in water supply; the estimated volume of these sediments is 883,126,432 cubic yards. The gross composition of rounded fragments in the outwash mass is made of averaging 42.86 percent of calcareous rocks, 30.61 percent of crystalline rocks, and 25.25 percent of clastic rock; silt and clay fraction averages 2.11 percent in weight, which tentatively shows the plasticity index of these sediments is low, and they are good material for use as highway paving and concrete aggregate.

The main bodies of shallow water flow along pre-moraine valley channels with moderate to low hydraulic gradients from east toward northwest, and make an oblique angle with the present major intermittent stream.

Water storage capacity is computed as 7,848,044,022 cubic feet or 180,166 acre-feet within 81,861 acres on the basis of porosity of sand and gravel, which is regionally assumed. During normal climatic conditions the capacity of the reservoir is 186,166 acre-feet. This capacity could supply enough water for the irrigation of 81,861 acres of farming land. The amount of water in the reservoir in the summer season of 1955, however, is estimated as 1,212,394,154 cubic feet or 27,832 acre-feet.

Quality of water is hard, however, it is satisfactory for domestic use. Sulfate, calcium and bicarbonate are the principal salts; alkali, magnesium, chloride, nitrate, fluoride, and manganese are subordinate in amount.

Suggestions for the future development of irrigation tentatively include depth of wells, character of soil, and quality of water. Sprinkling systems for irrigation will be very successful.

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APPENDIX

WELL LOGS IN OUTWASH SEDIMENTS

Lebanon City Well

Location: Section 4
Township 118 North,
Range 74 West, Potter County
Land Owner: Lebanon City

Operator: Lebanon City
Elevation: 1939 feet
Total Depth: 17 feet

Thickness (feet)	Description
0 - 1	Soil, darkish brown, leached, with a considerable amount of carbonaceous material. Somewhat sandy, chiefly of very fine-grained quartz grains.
1 - 2	Soil, darkish brown, leached, with a considerable amount of fine to medium grained quartz grains, and some carbonaceous materials.
2 - 3	Clay, gray to blackish gray, silty, somewhat sandy, calcareous, with distinct traces and patches of bentonitic materials, which consist chiefly of nontronite. Medium to coarse grained sands are commonly present at the basal part.
3 - 4	Sand, gray to buff, medium-to coarse-grained with rounded to subangular grains. Rounded rock fragments are sporadically present. Pink potash feldspar, and iron-oxides, which are commonly coated on quartz grains surface are fairly abundant.
4 - 5	Sand, brownish gray, medium to very coarse-grained, chiefly with rounded to subangular grains. Iron-oxides, pink potash feldspar and rounded rock fragments are generally present.

Thickness (feet)	Description
5 - 7	Sand and gravel, gray to buff, somewhat brown with medium to coarse-grained sand grains, and rounded rock fragments, which are constituted chiefly of igneous, metamorphic and sedimentary rock types. Among them granite, schist, limestone, dolomite and shale are predominant. The diameter ranges from 0.2 to 0.4 inches. Pink potash feldspars and iron-oxides are fairly common.
7 - 8	Sand and gravel, gray to buff, somewhat brownish gray, chiefly with coarse-grained sand grains and comparatively abundant rounded rock fragments, which consist of the same assemblage of rock types as the foregoing sample. The diameter ranges from 0.5 to 0.4 inches.
8 - 9	Sand and gravel, gray to buff, with a considerable amount of coarse-grained quartz grains and rounded rock fragments, in which granite, amphibolite schist and shale are rather abundant.
9 - 10	Sand and gravel, gray to slightly buff, with medium-to coarse-grained quartz grains and sporadic rounded rock fragments. Clay and silt are generally intercalated.
10 - 11	Sand and gravel, gray to buff, consisting chiefly of coarse-grained quartz grains, and comparatively abundant rounded rock fragments, in which shales are predominant. A distinct amount of bentonitic clay is scattered through the mass.
11 - 12	Sand and gravel, gray to buff, consisting mostly of medium-to

Thickness (feet)	Description
	coarse-grained quartz grains, and rather abundant rounded rock fragments in which the Pierre shale is the main constituent and pink granite, schist, and iron-oxides are subordinate in amount.
12 - 13	Same as the sample 11 - 12.
13 - 14	Sand and gravel, gray to buff, consisting chiefly of coarse-grained quartz grains, and rather abundant shale fragments. Pink potash feldspar, granite, iron-oxide and schist pebbles are sporadic.
14 - 15	Sand and gravel, buff, gray, chiefly of coarse-grained rounded to sub-rounded quartz grains, and rather abundant rock fragments. Pink potash feldspars, iron-oxides, quartz and schist are scattered through the mass.
15 - 17	Sand and gravel, gray to blackish gray, with fine, medium to rather coarse-grained, chiefly rounded quartz grains, and scattered rounded rock fragments. Clay-rich material common.
	- Unconformity -
17	Till, olive-green when moist, blackish-gray, when dry with a considerable amount of pebbles. Sandy (Cary?).

Habler Well

Location: Section 5
Township 120 North
Range 74 West, Potter County
Land Owner: Habler

Operator: Habler
Elevation: 1894 feet
Total depth: 17 feet

Thickness (feet)	Description
0 - 1.15	Soil, darkish brown to dark, leached, scattered medium-to coarse-grained quartz grains present at the basal part.
1.15 - 2.95	Clay, gray to blackish gray, somewhat sandy, with distinct traces and patches of bentonitic materials in which nontronite is the chief constituent.
2.95 - 3.90	Sand and gravel, with medium-to coarse-grained rounded to sub-angular quartz grains, and abundant rounded rock fragments in which gray to blackish gray laminated Pierre shales are predominant. Pink potash feld-spars and iron-oxides are spo-radically present.
3.90 - 4	Sand, buff, fine-to medium-grained rounded to subangular quartz grains. Rounded rock fragments are occasionally scattered through. Pink potash feldspars are not uncommon.
4 - 13	Sand and gravel, gray to slightly buff, with fine- to medium- to coarse-grained, rounded to subangular quartz grains, and an assemblage of sedimentary and igneous rock types, in which shales, limestone and granite are the chief constituents. Pink potash feldspars, iron-oxides and schists are sporadically

Thickness (feet)	Description
	present. The diameter of rounded rock fragments ranges up to 0.5 inches.
	- Unconformity -
13 - 14	Till, blackish gray, olive green, when moist, gray to blackish gray when dry, with medium- to coarse-grained sand grains, and scattered pebbles of Pierre shale and granites.
14 - 15	Till, same as the foregoing sample. Bentonitic materials and shale fragments are sporadically present. Boulder size rock fragments occasionally appear at the base. The average diameter of the rock fragments ranges from 0.2 to 0.6 inches.
15 - 16	Till, sandy, gray to blackish gray, pebbles in silt-rich matrix blackish gray clay generally abundant. Rock fragments are sporadic.
16 - 17	Till, sandy, gray to blackish gray somewhat olive green when moist, pebbles in clay-rich matrix, pebble size rock fragments are scarce.

Simons Well

Location: Section 32
Township 119 North
Range 74 West, Potter County
Land Owner: P. H. Simons

Operator: P. H. Simons
Elevation Bar: 1939 feet
Total Depth: 19 feet

Thickness (feet)	Description
0 - 2	Soil, darkish brown, leached, with a considerable amount of humus materials and somewhat sandy at the base.
2 - 4	Clay, gray to blackish gray, silty, somewhat sandy at the base, calcareous with distinct patches of bentonitic materials.
4 - 7	Sand and gravel, gray, medium- to coarse-grained, rounded to subangular quartz grains. Rounded rock fragments consisting of pink granite, shale, limestone, dolomite and schist are fairly common and range up to 0.3 inches in diameter. Pink potash feldspars, iron-oxides and chert are sporadic.
7 - 11	Sand and gravel, gray to buff, coarse-grained, rounded to subangular quartz grains, sporadically with rounded rock fragments, detrital minerals, potash feldspars, iron-oxides and others are generally present.
11 - 15	Sand and gravel, gray to somewhat buff, medium- to coarse-grained, rounded to subangular quartz grains with scattered rock fragments which consist chiefly of shale, granite and metamorphic rock types. Iron-oxides, and pink potash feldspars are common.

Thickness (feet)	Description
15 - 16	Sand and gravel, gray to buff, medium to coarse grained, rounded to subangular quartz grains, with rather abundant rounded to subangular rock fragments which are composed of shale, pink granite, and other sedimentary rocks and range from 0.05 to 0.25 inches in diameter. Pink potash feldspars and tourmaline are scattered through the mass.
	- Unconformity -
16 - 18	Till, sandy, olive green to bluish gray when moist, gray to blackish gray when dry, with scattered rock fragments which are up to 0.3 inches in diameter. Calcareous, bentonitic material is common.
18 - 19	Till, same as 16 - 18 samples.

TABLE 3

RESISTIVITY DATA ON THE THICKNESS OF SAND AND GRAVEL

Station No.	Location	Elevation Datum: Sea Level (feet)			Thickness (feet)	
		Surface	Sand & Gravel		Sand & Gravel	Mantle
			Top	Bottom		
49	Sec12 T118N, R74W	1988.46	1986	1979	7	2.46
50	Sec11 T118N, R74W	1972.46	1970	1941	29	2.46
51	Sec11 T118N, R74W	1960.46	1958	1941	17	2.46
11	Sec11 T118N, R74W	1968.96	1967	1961	6	1.96
10	Sec11 T118N, R74W	1961.46	1960.5	1955	5.5	0.96
52	Sec3 T118N, R74W	1964.56	1961	1950	11.0	3.56
9	Sec9 T118N, R74W	1933.46	1935	1928	7.0	2.46
95	Sec9 T118N, R74W	1931.50	1928	1925	3.0	3.50
8	Sec8 T118N, R74W	1920	1916	1915	1.0	4.0
12	Sec5 T118N, R74W	1917.96	1916	1910	6.0	1.96
71	Sec5 T118N, R74W	1941.46	1939	1927	12.0	2.46
53	Sec 3 T118N, R74W	1969.56	1968	1918	50.0	1.56
55	Sec3 T118N, R74W	1939	1936	1918	18.0	3.00
57	Sec3 T118N, R74W	1957.56	1948	1919	29.0	9.56
54	Sec3 T118N, R74W	1947.96	1945	1924	21.0	2.96
13	Sec35 T119N, R74W	1954	1950	1927	23.0	4.00
73	Sec33 T119N, R74W	1949.46	1947	1930	17.0	2.46
94	Sec33 T119N, R74W	1944	1940	1928	12.0	4.00

Station No.	Location	Elevation Datum: Sea Level (feet)			Thickness (feet)	
		Surface	Sand & Gravel		Sand & Gravel	Mantle
			Top	Bottom		
30	Sec33 T119N, R74W	1949	1944	1939	5.0	5.00
72	Sec32 T119N, R74W	1951.46	1945	1939	6.0	6.46
31	Sec32 T119N, R74W	1926.14	1925	1920	5.0	1.14
70	Sec32 T119N, R74W	1948	1946	1939	7.0	2.00
29	Sec34 T119N, R74W	1933.50	1932	1926	6.0	1.50
59	Sec34 T119N, R74W	1960	1953	1932	21.0	7.00
16	Sec28 T119N, R74W	1946	1943	1935	8.0	3.00
17	Sec28 T119N, R74W	1940	1932	1908	24.0	8.00
14	Sec28 T119N, R74W	1958	1955	1948	7.0	3.00
62	Sec28 T119N, R74W	1947	1944	1935	9.0	3.00
60	Sec27 T119N, R74W	1973	1967	1942	25.0	6.00
61	Sec27 T119N, R74W	1977	1973	1962	11.0	4.00
63	Sec27 T119N, R74W	1971	1967	1917	50.0	4.00
64	Sec27 T119N, R74W	1962	1958	1928	30.0	4.00
20	Sec22 T119N, R74W	1963	1962	1949	13.0	1.00
21	Sec22 T119N, R74W	1965.5	1964	1957	7.0	1.50
23	Sec22 T119N, R74W	1950	1946	1943	3.0	4.00
19	Sec21 T119N, R74W	1958.5	1957	1951	6.0	1.50
28	Sec21 T119N, R74W	1954.5	1952	1942	30.0	2.50
24	Sec21 T119N, R74W	1956.85	1948	1912	36.0	6.85
65	Sec21 T119N, R74W	1950	1948	1937	11.0	2.00
15	Sec21 T119N, R74W	1955.25	1948	1941	7.0	7.25

Station No.	Location	Elevation Datum: Sea Level (feet)			Thickness (feet)	
		Surface	Sand & Gravel		Sand & Gravel	Mantle
			Top	Bottom		
25	Sec20 T119N, R74W	1952.25	1950	1942	8.0	2.25
26	Sec20 T119N, R74W	1940	1937	1930	7.0	3.00
93	Sec20 T119N, R74W	1950.85	1949	1915	34.0	1.85
32	Sec16 T119N, R74W	1970.35	1967	1954	13.0	3.35
66	Sec16 T119N, R74W	1972	1969	1964	5.0	3.00
67	Sec9 T119N, R74W	1970.5	1969	1967	2.0	1.50
68	Sec9 T119N, R74W	1955	1953	1934	19.0	2.00
43	Sec9 T119N, R74W	1948	1946	1933	13.0	2.00
38	Sec8 T119N, R74W	1939.65	1938	1918	20.0	1.65
46	Sec5 T119N, R74W	1948.15	1945	1943	2.0	3.15
74	Sec5 T119N, R74W	1945	1937	1912	25.0	8.00
45	Sec4 T119N, R74W	1963	1955	1901	54.0	8.00
75	Sec32 T120N, R74W	1949	1947	1930	17.0	2.00
92	Sec32 T120N, R74W	1929	1921	1899	22.0	8.00
76	Sec32 T120N, R74W	1947	1943	1887	56.0	4.00
47	Sec33 T120N, R74W	1969	1964	1878	86.0	5.00
48	Sec33 T120N, R74W	1962	1958	1902	56.0	4.00
82	Sec33 T120N, R74W	1953	1951	1946	5.0	2.00
81	Sec33 T120N, R74W	1965	1959	1871	88.0	6.00
83	Sec33 T120N, R74W	1961	1958	1874	84.0	3.00
79	Sec28 T120N, R74W	1965	1960	1912	48.0	5.00
80	Sec28 T120N, R74W	1960	1956	1872	84.0	4.00

Station No.	Location	Elevation Datum: Sea Level (feet)			Thickness (feet)	
		Surface	Sand & Gravel		Sand & Gravel	Mantle
			Top	Bottom		
84	Sec28 T120N, R74W	1964	1962	1878	84.0	2.00
85	Sec28 T120N, R74W	1960	1956	1845	111.0	4.00
90	Sec28 T120N, R74W	1956.2	1952	1882	70.0	4.20
86	Sec28 T120N, R74W	1957.15	1952	1860	92.0	5.15
77	Sec28 T120N, R74W	1961	1953	1879	74.0	8.00
91	Sec29 T120N, R74W	1957.15	1952	1857	95.0	5.15
87	Sec29 T120N, R74W	1946.95	1945	1917	28.0	1.95
88	Sec29 T120N, R74W	1943.95	1942	1889	53.0	1.95
122	Sec19 T120N, R74W	1923.65	1918	1901	17.0	5.65
128	Sec19 T120N, R74W	1928.15	1921	1899	22.0	7.15
121	Sec20 T120N, R74W	1935.15	1930	1906	24.0	5.15
115	Sec20 T120N, R74W	1922.55	1915	1891	24.0	7.55
96	Sec21 T120N, R74W	1938.35	1936	1907	29.0	2.35
97	Sec21 T120N, R74W	1934.28	1930	1882	48.0	4.28
98	Sec21 T120N, R74W	1938.38	1936	1899	37.0	2.38
99	Sec21 T120N, R74W	1949.88	1932	1903	29.0	17.88
100	Sec22 T120N, R74W	1963	1961	1897	64.0	2.00
101	Sec15 T120N, R74W	1966.28	1964	1919	45.0	2.28
102	Sec15 T120N, R74W	1948.48	1933	1891	42.0	15.48
103	Sec15 T120N, R74W	1945.55	1941	1890	51.0	4.55
104	Sec9 T120N, R74W	1929.9	1928	1911	17.0	1.90
106	Sec16 T120N, R74W	1913.3	1910	1865	45.0	3.30

Station No.	Location	Elevation Datum: Sea Level (feet)			Thickness (feet)	
		Surface	Sand & Gravel		Sand & Gravel	Mantle
			Top	Bottom		
116	Sec17 T120N, R74W	1911.92	1908	1897	11.0	3.92
117	Sec17 T120N, R74W	1912.8	1908	1889	19.0	4.80
123	Sec18 T120N, R74W	1886.1	1886	1868	18.0	0.1
127	Sec12 T120N, R75W	1897.9	1893	1880	13.0	4.90
126	Sec7 T120N, R74W	1900.3	1897	1880	17.0	3.30
118	Sec8 T120N, R74W	1898.5	1894	1863	31.0	4.50
119	Sec8 T120N, R74W	1906.43	1902	1896	6.0	4.43
108	Sec9 T120N, R74W	1913.4	1909	1895	14.0	4.40
105	Sec9 T120N, R74W	1927.75	1921	1871	50.0	6.75
125	Sec5 T120N, R74W	1893.95	1891	1883	8.0	2.95
120	Sec5 T120N, R74W	1909.95	1903	1832	71.0	6.95
109	Sec4 T120N, R74W	1956.80	1956	1943	13.0	0.80
110	Sec4 T120N, R74W	1933.95	1922	1836	86.0	11.95
111	Sec4 T120N, R74W	1924.65	1917	1860	57.0	7.65
112	Sec4 T120N, R74W	1947.80	1933	1891	42.0	14.80
113	Sec4 T120N, R74W	1963.80	1949	1848	101.0	14.80

ERRATA

Column 9 of Table 8 should read;-

"Height Above
Ground Level
(in.)"

TABLE 8

WELL RECORDS
(JULY-AUGUST, 1955)

No. on Map	Location	Owner or Tenant	Type of Well	Depth of Well	Dia. of Well	Type of Casing	Top Edge of Casing
20	Sec8 T118N R74W	S. Simon	Du	30	24x29	wood	wood
21	Sec8 T118N R74W	S. Simon	Du	30	29	wood	wood
22	Sec8 T118N R74W	S. Simon	Du	52	24	wood	wood
18	Sec11 T118N R74W	P. Mikkelson	Du	28	48	cement, steel	wood
19	Sec11 T118N R74W	P. Mikkelson	Du	30	6	steel	steel
89	Sec12 T118N R74W	J. Knott	Du	48	36	wood	wood
39	Sec2 T118N R74W	E. Breen	Du	30	24	wood	wood
40	Sec2 T118N R74W	E. Breen	Du	32	24	wood	wood
41	Sec2 T118N R74W	E. Breen	Du	30	24	wood	wood
42	Sec2 T118N R74W	E. Breen	Du	14	24	wood	wood
73	Sec3 T118N R74W	D. Schneider	Du	14	36	steel	cement
74	Sec3 T118N R74W	D. Schneider	Du	14	36	steel	cement
75	Sec3 T118N R74W	D. Schneider	Du	14	36	steel	cement
66	Sec4 T118N R74W	R. O. Beach	Du	21	29	steel	wood
67	Sec4 T118N R74W	R. O. Beach	Du	21	29	steel	cement
69	Sec4 T118N R74W	W. Baum	Du	16	10	tile	tile
70	Sec4 T118N R74W	W. Baum	Du	15	10	tile, steel	cement
71	Sec4 T118N R74W	L. Whitney	Du	20	24	cement	cement
72	Sec4 T118N R74W	O. Veil	Du	17	14	steel	cement
144	Sec4 T118N R74W	E. Lee	Du	13	12	steel	wood, cement

Height Above Sea Level (In.)	Elev. Mean Sea Level (Ft.)	Principal Water Bearing Beds: Character of Material	Principal Water Bearing Beds: Geologic Source	Method of Lift	Use of Water	Date Drilled	Depth of Water (Summer '55)
24	1938	Till	Iowan	PW	DS	1930	15
24	1939	Till	Iowan	PWH	D	1940	11
1.7	1939	Till, Shale	Iowan Pierre shale	PHE	DS	1949	10
4	1965	S & G	Outwash	PW (JE)	DS	1935	8
—	1959	S & G	Outwash	CYE	D	1945	11
24	—	Till Shale	Cary-Pierre Shale	PW	D	1936	0.5
24	1972	S & G	Outwash	PW	D	1920	3
24	1972	S & G	Outwash	PW	D	1948	3
24	1972	S & G	Outwash	PW	D	1948	1
24	1955	S & G	Outwash	PW	S	1954	8
10	1944	S & G	Outwash	PW	DS	1922	6
10	1944	S & G	Outwash	PW	D	1922	6
10	1944	S & G	Outwash	PW	D	1922	6
8	1940	S & G	Outwash	PH	D	1948	6
0	1934	S & G	Outwash	CYE	D	1948	6
6	1943	S & G	Outwash	CYE	D	1907	8
12	1943	S & G	Outwash	JE	D	1951	7
4	1945	S & G	Outwash	CYE	D	1951	2
4	1945	S & G	Outwash	CYE	D	1951	10
24	1950	S & G	Outwash	JE	D	1948	5.5

TABLE 8

WELL RECORDS
(JULY-AUGUST, 1955)

No. on Map	Location	Owner or Tenant	Type of Well	Depth of Well	Dia. of Well	Type of Casing	Top Edge of Casing
140	Sec4 T118N R74W	J.P.WALDNER	DU	16	6	STEEL	WOOD, CEMENT
141	Sec4 T118N R74W	J.P.WALDNER	DU	15	18	WOOD	WOOD
142	Sec4 T118N R74W	C.HOFFMAN	DU	14	8	STEEL	STEEL, CEMENT
143	Sec4 T118N R74W	A.VEIGT	DU	13	48	WOOD	CEMENT
62	Sec4 T118N R74W	CITY OF LEBANON	DU	18	44	CEMENT	CEMENT
63	Sec4 T118N R74W	CITY OF LEBANON	DU	20	72	STEEL	STEEL
88	Sec4 T118N R74W	E.R.VEIL	DU	18	23	CEMENT TILE	CEMENT
45	Sec4 T118N R74W	A.WAIL	DU	10	10	STEEL	WOOD
46	Sec4 T118N R74W	A.WAIL	DU	12	10	STEEL	STEEL
52	Sec6 T118N R74W	M.SIMON	DR	110	16	WOOD	WOOD
53	Sec6 T118N R74W	M.SIMON	DU	40	24	WOOD	WOOD
55	Sec6 T118N R74W	M.SIMON	DU	66	30	WOOD	WOOD
54	Sec5 T118N R74W	M.SIMON	DU	18	24	WOOD	WOOD
86	Sec32 T119N R74W	P.H.SIMON	DU	18	23	TILE, CEMENT	CEMENT
34	Sec32 T119N R74W	P.H.SIMON	DU	19	24	WOOD	CEMENT
35	Sec32 T119N R74W	P.H.SIMON	DU	19	8	STEEL	STEEL
36	Sec32 T119N R74W	P.H.SIMON	DU	19	8	STEEL	STEEL
58	Sec31 T119N R74W	J.COLLINS	DU	40	24	WOOD	WOOD
59	Sec31 T119N R74W	J.COLLINS	DU	40	24	WOOD	WOOD
60	Sec31 T119N R74W	J.COLLINS	DU	40	24	WOOD	WOOD

Height Above Sea Level (in.)	Elev. Mean Sea Level (ft.)	Principal Water Bearing Beds: Character of Material	Principal Water Bearing Beds: Geologic Source	Method of Lift	Use of Water	Date Drilled	Depth of Water (summer '55)
28	1940	S & G	Outwash	PH	D	1952	6
12	1935	S & G	Outwash	PW	D	1922	9.6
17	1945	S & G	Outwash	PH	D	1955	7
—	1946	S & G	Outwash	PH	D	1947	6
12	1943	S & G	Outwash	CYE	P	1955	12
8	1943	S & G	Outwash	JE	P	1930	9
24	1945	S & G	Outwash	CYE JE	D	1951	11
29	1950	S & G	Outwash	PW	D	1918	5
12	1949	S & G	Outwash	JE	D	1948	5
12	1947	Till Shale	Iowan-Pierre Shale	PW	DS	1954	18
48	1939	Till Shale	Iowan-Pierre Shale	PW	DS	1950	30
48	1937	Till Shale	Iowan-Pierre Shale	JE	DS	1955	50
48	1947	S & G	Outwash	PW	S	1955	8
8	1940	S & G	Outwash	JE	D	1955	8
12	1941	S & G	Outwash	PW	DS	1941	9
—	1938	S & G	Outwash	CYE	D	1950	10
—	1938	S & G	Outwash	CYE	D	1948	9
7	1929	Till Shale	Iowan-Pierre Shale	PW	DS	1941	24
12	1950	Till Shale	Shale, Iowan-Pierre	PW	S	1952	28
12	1954	Till Shale	Shale, Iowan-Pierre	PW	S	1924	30

TABLE 8

WELL RECORDS
(JULY-AUGUST, 1955)

NO. ON MAP	LOCATION	OWNER OR TENANT	TYPE OF WELL	DEPTH OF WELL	DIA. OF WELL	TYPE OF CASING	TOP EDGE OF CASING
61	SEC31 T119N R74W	J.COLLINS	DU	45	24	WOOD	WOOD
10	SEC28 T119N R74W	H.G.DAHLQUIST	DU	24	24	WOOD	CEMENT
11	SEC28 T119N R74W	H.G.DAHLQUIST	DU	24	24	ROCK, CEMENT	CEMENT
12	SEC28 T119N R74W	H.G.DAHLQUIST	DU	24	24	WOOD	WOOD
13	SEC28 T119N R74W	H.G.DAHLQUIST	DU	18	18	CEMENT, TILE	CEMENT
37	SEC34 T119N R74W	A.E.LUNDA	DU	40	36	STEEL	CEMENT
38	SEC34 T119N R74W	A.E.LUNDA	DU	40	36	STEEL	STEEL
50	SEC35 T119N R74W	F.BECKER	DU	30	24	WOOD	WOOD
51	SEC35 T119N R74W	F.BECKER	DU	30	24	TILE	TILE
84	SEC27 T119N R74W	C.DAHLQUIST	DU	28	24	STEEL	CEMENT
81	SEC22 T119N R74W	H.JORDETH	DU	45	36	CEMENT, ROCK	CEMENT
82	SEC22 T119N R74W	H.JORDETH	DU	35	36	CEMENT, ROCK	CEMENT
83	SEC22 T119N R74W	H.JORDETH	DU	35	36	WOOD	WOOD
87	SEC21 T119N R74W	P.H.SIMON	DU	18	23	WOOD	WOOD
26	SEC20 T119N R74W	E.NYLANDERD	DU	15	24	WOOD	WOOD
27	SEC17 T119N R74W	E.NYLANDERD	DU	15	36	WOOD	WOOD
28	SEC17 T119N R74W	E.NYLANDERD	DU	18	24	WOOD	WOOD
29	SEC17 T119N R74W	E.NYLANDERD	DU	20	24	WOOD	WOOD
30	SEC17 T119N R74W	E.NYLANDERD	DU	18	24	WOOD	WOOD

Height Above Sea Level (In.)	Elev. Mean Sea Level (Ft.)	Principal Water Bearing Beds Character of Material	Geologic Source	Method of Lift	Use of Water	Date Drilled	Depth of Water (Summer '55)
12	1957	Till Shale	Iowan-Pierre Shale	PW	S	1924	35
5	1959.5	S & G	Outwash	PW	D	1916	5
5	1960	S & G	Outwash	PW	D	1934	5
5	1960	S & G	Outwash	PW	DS	1946	5
—	1952	S & G	Outwash	CYE	D	1951	5
24	1960	S & G	Outwash	PW	D	1885	5
6	1959	S & G	Outwash	PW	DS	1927	27
36	1979	S & G	Outwash	PW	D	1953	10
36	1974	S & G	Outwash	PW	DS	1953	4
12	1964	S & G	Outwash	PW	D	1925	5
8	1976	S & G	Outwash	PW	D	1905	4
10	1970	S & G	Outwash	JE	DS	1940	5
12	1975	S & G	Outwash	PW	S	1920	4
18	1958	S & G	Outwash	PW	S	1941	4
18	1938	S & G	Outwash	PW	S	1939	4
24	1955	Clay, Silt, Sand, Till	Alluvium, Iowan	PW	D	1940	5
36	1957	Clay, Silt, Sand, Till	Alluvium, Iowan	PW	D	1943	8
24	1955	Till Shale	Iowan-Pierre Shale	PW	D	1915	10
24	1957	Till Shale	Iowan-Pierre Shale	PW	D	1927	3

TABLE 8

WELL RECORDS
(JULY-AUGUST, 1955)

No. on Map	Location	Owner or Tenant	Type of Well	Depth of Well	Dia. of Well	Type of Casing	Top Edge of Casing
31	Sec17 T119N R74W	E.Nylanderd	Du	12	48	wood	wood
32	Sec16 T119N R74W	E.Nylanderd	Du	18	24	wood	wood
78	Sec9 T119N R74W	N.Simons	Du	13	36	tile, wood	tile
79	Sec9 T119N R74W	N.Simons	Du	14	48	wood	wood
80	Sec9 T119N R74W	N.Simons	Du	18	36	wood	wood
110	Sec8 T119N R74W	G.Hageman	Du	6	30	wood	wood
94	Sec5 T119N R74W	Mrs.Kulcker	Du	45	36	tile, wood	tile
76	Sec4 T119N R74W	S.Schumacher	Du	73	24	wood	wood
77	Sec4 T119N R74W	S.Schumacher	Du	80	24	wood	cement
33	Sec4 T119N R74W	P.P.Koehn	Du	65	24	wood	wood
3	Sec32 T120N R74W	S.Simon	Du	38	42	wood	cement
1	Sec29 T120N R74W	J.Weibel	Du	60	48	wood	wood
2	Sec29 T120N R74W	J.Weibel	Du	60	36	wood	wood
4	Sec28 T120N R74W	N.Simon	Du	49	24	wood	wood
5	Sec28 T120N R74W	N.Simon	Du	50	24	steel	cement
6	Sec27 T120N R74W	N.J.Muier	Du	65	24	wood	wood
7	Sec27 T120N R74W	N.J.Muier	Du	66.5	24	wood	wood
8	Sec27 T120N R74W	N.J.Muier	Du	85	36	wood	wood
9	Sec27 T120N R74W	N.J.Muier	Du	55	36	wood	wood

Height Above Sea Level (in.)	Elev. Mean Sea Level (ft.)	Principal Water Bearing Beds: Character of Material	Principal Water Bearing Beds: Geologic Source	Method of Lift	Use of Water	Date Drilled	Depth of Water (summer '55)
24	1945	Sand, Clay, silt,	Alluvium	PH	DS	1932	4
24	1971	Sand, gravel	Outwash	PW	S	1942	9
6	1947	S & G	Outwash	PHE	D	1955?	6
6	1950	S & G	Outwash	PW	DS	1910?	5
8	1950	S & G	Outwash	PW	DS	1954	8
36	1921	Silt, sand	Alluvium	PW	S	1945	3
18	1950	S & G, Till, shale	Outwash Pierre shale	PW	D	1955	35
18	1957	Till, Shale	Cary Pierre shale	CYE	D	1948	12
12	1962	Till, Shale	Cary Pierre shale	PW	S	1916	52
12	1955	S & G Till?	Outwash	PW JE	DS	1905	24
6	1950	S & G	Outwash	PW JE	D	______	8
8	1955	S & G	Valley train	PW	D	______	20
9	1955	S & G	Valley train	E PH	DS	______	10
5	1951	S & G	Outwash	PW	DS	______	4
4.5	1952	S & G	Outwash	JE	D	1948	4
8	1969	S & G	Outwash	PW	D	1905	7.5
8	1969	S & G	Outwash	PW JE	D	1950	8
8	1969	S & G	Outwash	PW	DS	1942	18
8	1969	S & G	Outwash	PW	DS	1942	17

TABLE 8

WELL RECORDS
(JULY-AUGUST, 1955)

NO. ON MAP	LOCATION	OWNER OR TENANT	TYPE OF WELL	DEPTH OF WELL	DIA. OF WELL	TYPE OF CASING	TOP EDGE OF CASING
130	SEC27 T120N R74W	F. KAUP	DU	65	24	WOOD	WOOD
91	SEC20 T120N R74W	W. VANWELL	DU	27	18	STEEL	CEMENT
92	SEC20 T120N R74W	W. VANWELL	DU	30	18	STEEL	CEMENT
109	SEC20 T120N R74W	G. HAGEMAN	DU	16	24	WOOD	WOOD
128	SEC20 T120N R74W	W. SIMON	DU	28	30	TILE	TILE
129	SEC20 T120N R74W	W. SIMON	DU	28	24	WOOD	WOOD
116	SEC19 T120N R74W	F. RONDORF	DU	20	24	TILE, CEMENT	CEMENT
93	SEC24 T120N R74W	R. DEROUCHEY	DU	15	48	CEMENT	CEMENT
111	SEC22 T120N R74W	MRS. F. ZWEBER	DU	65	36	TILE	WOOD
138	SEC23 T120N R74W	R. ZWEBER	DU	38	24	WOOD	WOOD
139	SEC23 T120N R74W	R. ZWEBER	DU	34	24	WOOD	WOOD
95	SEC15 T120N R74W	C. REDINGER	DU	65	36	WOOD	WOOD
96	SEC15 T120N R74W	C. REDINGER	DU	42	24	CEMENT, TILE	WOOD
97	SEC14 T120N R74W	C. REDINGER	DU	35	24	WOOD	WOOD
98	SEC10 T120N R74W	C. REDINGER	DU	40	24	WOOD	WOOD
104	SEC16 T120N R74W	J. SEURER	DU	16	36	WOOD	WOOD
105	SEC16 T120N R74W	J. SEURER	DU	16	12	TILE	TILE
106	SEC16 T120N R74W	J. SEURER	DU	16	18	STEEL	STEEL
115	SEC18 T120N R74W	E. GERBER	DU	14	24	WOOD	WOOD, CEMENT

Height Above Sea Level (In.)	Elev. Mean Sea Level (Ft.)	Principal Water Bearing Beds: Character of Material	Principal Water Bearing Beds: Geologic Source	Method of Lift	Use of Water	Date Drilled	Depth of Water (Summer '55)
18	1963	Till S & G	Cary, Outwash	PW	S	1925	10
18	1923	S & G	Valley Train	PW	DS	1949	25
6	1930	S & G	Valley Train	JE	D	1955	3
24	1935	S & G	Outwash	PW	D	———	5
18	1935	S & G	Outwash	PW	D	1925	11
8	1935	S & G	Outwash	PH	D	1951	8
6	1904	S & G	Valley Train	PW	DS	1927	4
30	1867	S & G	Valley Train	PW E	DS	1920	7
36	1959	S & G	Outwash	PW E	DS	1910	10
8	1913	Till	Cary	PW H	DS	1945	12
12	1913	Till, S & G	Cary, Outwash	E PW	DS	1951	11
18	1939	S & G	Outwash	PW	S	1895	9
18	1952	S & G	Outwash	PW JE	D	1915	9
30	1934	S & G, Till	Cary	PW	S	1955	?
24	1932	S & G, Till	Cary	PW	S	1941	?
30	1915	S & G	Outwash	PW	D	1921	4
6	1910	S & G	Outwash	CYE	D	1921	5
6	1908	S & G	Outwash	CYE	D	1921	5
12	1915	S & G	Valley Train	PW	DS	1933	6

TABLE 8

WELL RECORDS
(JULY-AUGUST, 1955)

NO. ON MAP	LOCATION	OWNER OR TENANT	TYPE OF WELL	DEPTH OF WELL	DIA. OF WELL	TYPE OF CASING	TOP EDGE OF CASING
124	SEC13 T120N R74W	J.REDING	DU	14	36	TILE	CEMENT
136	SEC13 T120N R75W	H.MEYER	DU	17	36	WOOD	WOOD
137	SEC13 T120N R75W	H.MEYER	DU	26	24	STEEL	STEEL
114	SEC12 T120N R75W	F.RAUSCH	DU	17	12	STEEL	STEEL
117	SEC8 T120N R74W	N.HERICKS	DU	14	36	TILE	TILE
108	SEC8 T120N R74W	J.SEURER	DU	16	18	STEEL	STEEL
100	SEC9 T120N R74W	W.SIMON	DU	49	36	TILE, CEMENT	CEMENT
101	SEC9 T120N R74W	W.SIMON	DR	80	36	WOOD	WOOD
102	SEC3 T120N R74W	H.HAGEMAN	DR	60	24	WOOD	WOOD
103	SEC4 T120N R74W	W.KAISER	DR	65	24	TILE, WOOD	CEMENT
99A	SEC4 T120N R74W	CITY OF HOVEN	DR	60	24	CEMENT, TILE	CEMENT
99B	SEC5 T120N R74W	CITY OF HOVEN	DR	44	36	CEMENT, TILE	CEMENT
131	SEC5 T120N R74W	L.FROST	DR	49	24	WOOD, CEMENT	CEMENT
135	SEC5 T120N R74W	J.Y.VANWELL	DR	40	24	WOOD, STEEL	CEMENT
119	SEC5 T120N R74W	N.FROST	DU	16	24	WOOD	STEEL
120	SEC5 T120N R74W	N.FROST	DU	19	18	STEEL	STEEL
121	SEC5 T120N R74W	J.VANWELL	DU	12	24	WOOD	WOOD
112	SEC5 T120N R74W	H.ABLER	DU	17	24	TILE, WOOD	WOOD
122	SEC1 T120N R75W	W.RAUSCH	DU	15	24	TILE	CEMENT

Height Above Sea Level (in.)	Elev. Mean Sea Level (ft.)	Principal Water Bearing Beds: Character of Material	Principal Water Bearing Beds: Geologic Source	Method of Lift	Use of Water	Date Drilled	Depth of Water (summer '55)
6	1888	S & G	Valley train	PW	S	———	3
4	1871	S & G, silt	Valley train, Lake depts	PH JE	D	1905	7
10	1870	S & G, silt	Valley train, Lake depts	CYE	D	1945	6
24	1892	S & G	Valley train	PW JE	DS	1954	3
24	1898	S & G, Till	Valley train, Iowan?	PW	S	1951	3
30	1912	S & G	Outwash	PW	S	1950	5
18	1935	S & G	Outwash	PW JE	D	1951	8
36	1960	S & G, Till	Cary	PW	S	1951	2
12	1941	Till	Cary	PW JE	DS	1915	20
5	1957	S & G	Outwash	JE	D	1915	3
18	1928	S & G	Outwash	JE	D	1950	18
12	1935	S & G	Outwash	JE	D	1954	22
6	1934	S & G	Outwash	PW E	D	1925	9
6	1933	S & G	Outwash	PW E	D	1905	13
12	1922	S & G	Outwash	PW E	D	1925	5
6	1923	S & G	Outwash	JE	DS	1934	6
24	1894	S & G	Outwash	PW	S	1951	4
36	1894	S & G	Outwash	PW E	DS	1955	3
36	1892	S & G	Valley train	JE	D	1953	2.5

TABLE 8

WELL RECORDS
(JULY-AUGUST, 1955)

No. ON MAP	LOCATION	OWNER OR TENANT	TYPE OF WELL	DEPTH OF WELL	DIA. OF WELL	TYPE OF CASING	TOP EDGE OF CASING
123	SEC I T120N R75W	W. RAUSCH	DU	6	48	STEEL	STEEL
125	SEC I T120N R75W	J. KLOCKER	DU	14	30	TILE	TILE
126	SEC I T120N R75W	J. KLOCKER	DU	17	12	STEEL	STEEL

Height Above Sea Level (in.)	Elev. Mean Sea Level (ft.)	Principal Water Bearing Beds: Character of Material	Principal Water Bearing Beds: Geologic Source	Method of Lift	Use of Water	Date Drilled	Depth of Water (summer '55)
12	1879	S & G	Valley train	JE	S	1951	1
6.5	1900	S & G	Valley train	PW	DS	1905	4.5
6	1900	S & G	Valley train	JE	D	1954	5

C: Horizontal Centrifugal
Cy: Cylinder
J: Jet pump
P: Pitcher pump
T: Turbine
E: Electric

H: Hand operated
W: Windmill
D: Domestic
S: Stock
Dr: Drilled
Du: Dug
S & G: Sand & gravel