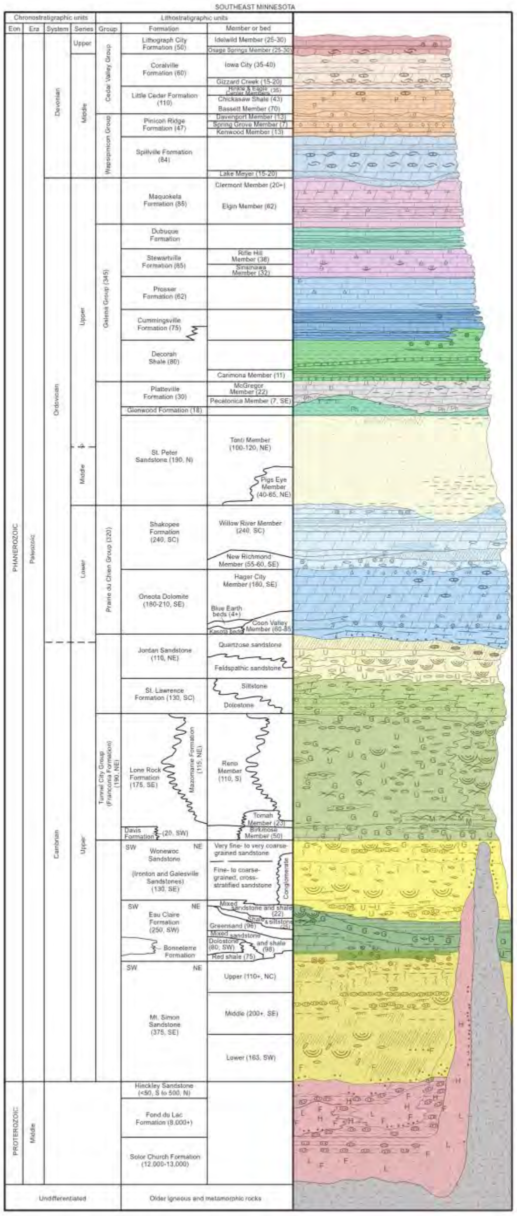
Chapter 5 - Rochester's Water Supply

Where does the water we drink come from? That is something many people do not think about. They turn on the faucet and water comes out. In Rochester, the City gets its water from deep under the ground. The entire process of taking the water from below ground and bringing it into the homes and businesses in Rochester is managed by Rochester Public Utilities (RPU). (For a brief history of Rochester's water supply, see Chapter 2.)

Rochester's earliest residents used surface water taken from the rivers to meet their personal and industrial needs. Today, Rochester's water supply is extracted from bedrock aquifers - large rock formations that hold water. Underground lakes or rivers that contain the water don't exist below Rochester. Rather, the water is held in small fractures within the rock layers or in the pore spaces between the particles that form the rock. Fractured limestone and porous sandstone are the aquifer forming rocks here. To be a dependable source of water, aquifers must be both porous, (meaning there are spaces for the water to be in) and permeable, (the water can move easily through the rock).

Most of Rochester's water comes from the Jordan Aquifer which is composed of sandstone. Rochester sometimes also uses other aquifers such as theSt Peter, Prairie du Chien limestone, the Ironton-Galesville sandstone, and the Mt. Simon sandstone.



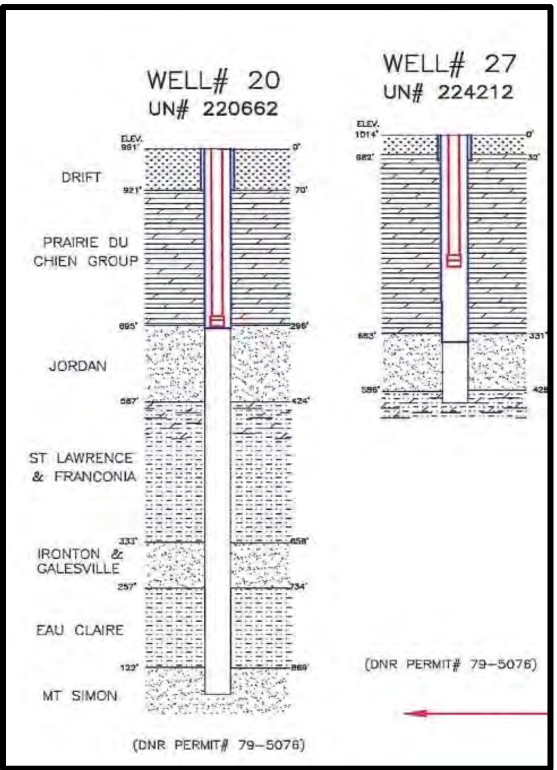
Source: modified from Mossler, J.H., Palezoic stratigraphic nomenclature for Minneosta. Minnesota Geological Survey Report if Investigations 65, 76 p.

Geologists use symbols to chart bedrock types. What symbols are used to represent sandstone and limestone in this geologic chart?

Rochester's Wells

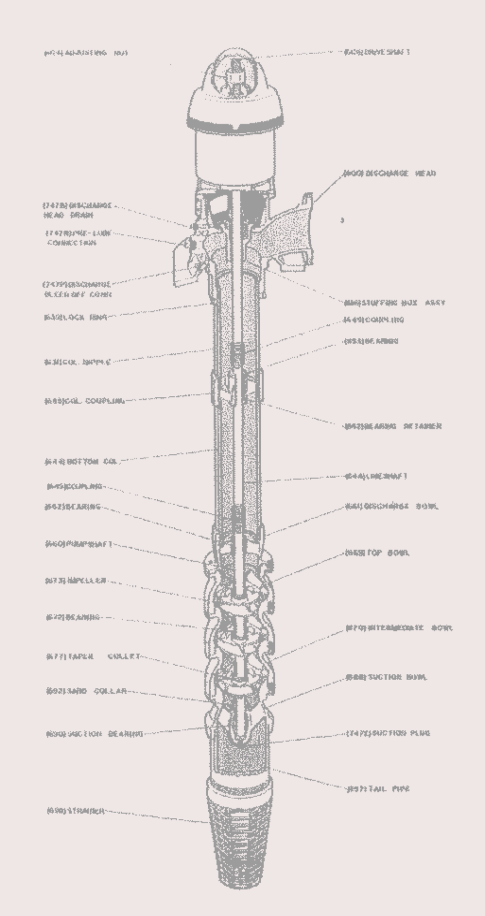
Water from the underground aquifers is drawn to the surface by 33 wells located throughout the city. Most of the wells are 24 inches in diameter and extend between 400 and 1,000 feet down into the earth. A pump is inserted into the well to bring water out of the ground.

Geologic Cross-Sections of Two RPU Water Supply Wells



Source: Rochester Public Utilities

Well Pump Schematic



Source: Rochester Public Utilities

While the method for collecting water is the same throughout Rochester, each well is a bit unique. Some older wells extract water from multiple aquifers while newer wells usually use only the Jordan aquifer. Connecting more than one aquifer within one well is a practice that has been discontinued where aquifers are separated by confining layers. This change was adopted to prevent contamination migrating from one aquifer into another. Rochester has limited the drilling of its municipal wells to the Jordan sandstone since 1980, as regulated by the Minnesota Department of Health.

Each well is housed in a building that matches the architecture of the area. The wells are numbered for ease of identification. Each well is continually monitored electronically by a computer system that automatically starts and stops pumping when water usage needs change or when water levels in towers reach different programmed levels. In addition, the computer system monitors the energy usage of the pumps and the water levels of the aquifers.

RPU Well Houses

Source: Rochester Public Utilities

In 2012, the average amount of water pumped by the City of Rochester was 13,183,000 gallons each day. The total amount of water pumped during 2012 was 4,825,000,000 gallons. This total was about 6 percent less than the record of 5,110,000,000 gallons set in 2007 for yearly volume pumped.

Currently, if all of Rochester's wells were pumping at full capacity, the system would be extracting 24,918 gallons per minute (gpm) or 35,882,000 gallons per day. RPU needs to plan for water usage peaks from increased water consumption so that water demands can be met without running out of water at any moment in time. The record for peak water demand was set in 2007 at 30,229,000 gallons of water pumped in one day during very warm weather and drought conditions.

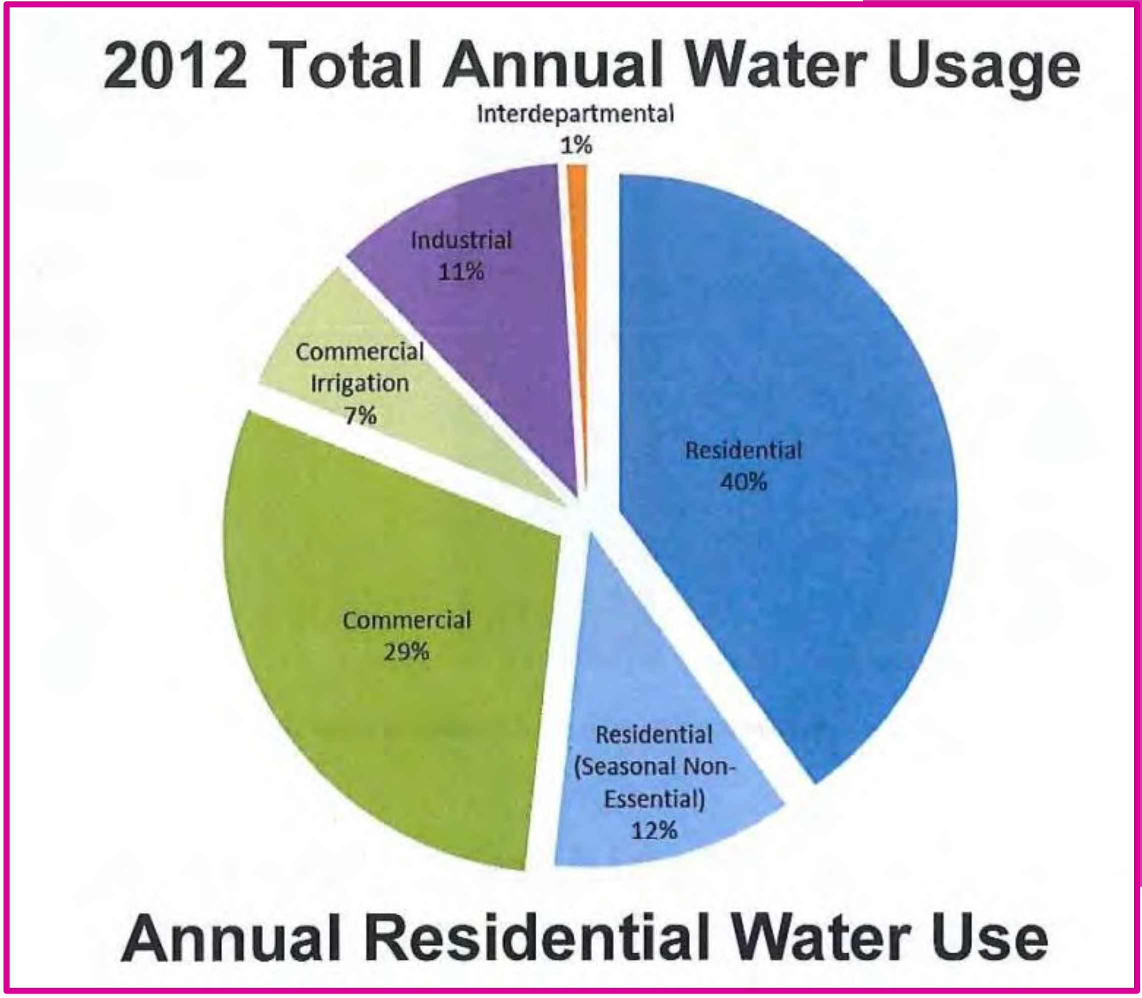
In April 2010, RPU launched a rebate program to encourage citizens to conserve water. In 2012 a total of 1,651 rebates totaling $204,763 were processed that year. It is estimated that the conservation practices put in place, as measured by the rebates, resulted in saving 9,280,206 gallons of water, the equivalent of over 25,425 gallons a day. Water conservation from the rebate program represents 0.19% of the total annual water consumption.

Conserve & Save Water Rebates Processed in 2012:

- 1,119 Clothes Washer - $27,975
- 86 Pressure Regulation Devices $258
- 334 High Efficiency Toilets - $16,850
- 76 Rain Barrels - $ 158.840
- 25 Rotating Sprinkler Nozzle - $75
- 4 High Efficiency Urinals $240
- 7 Weather-Based Irrigation Controllers $525

In 2010, RPU put water conservation rates into place to encourage conservation, by charging more for water when more is used.

RPU tracks how much water is used by each customer class. In the following chart, industries manufacture goods while commercial companies provide services. The "Residential (Seasonal Non-Essential" segment is the same as irrigation. The "Interdepartmental" segment is used by RPU. Overall, residential use makes up just over half of the total annual water use in Rochester.



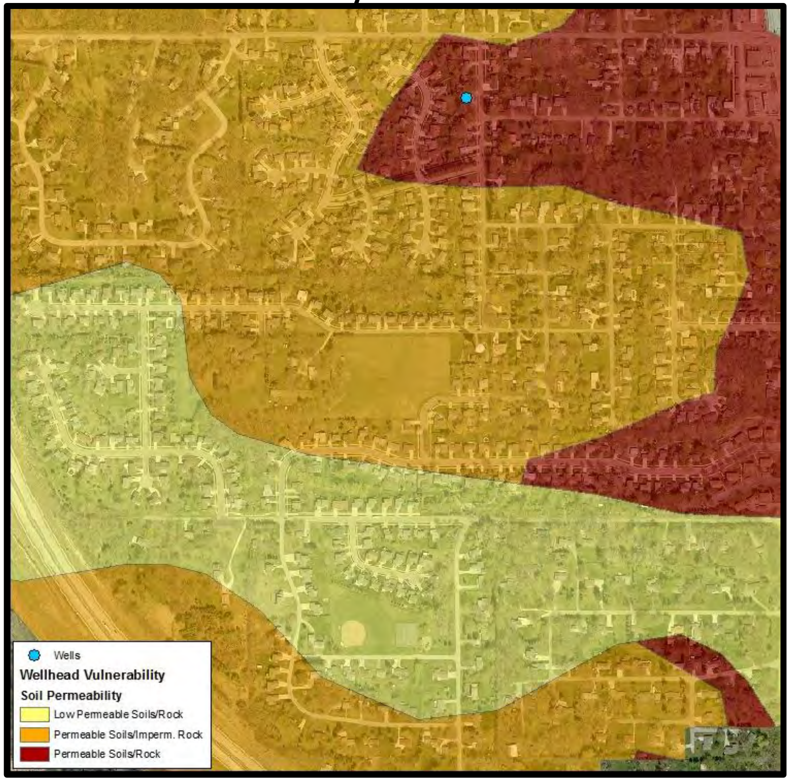
Source: Rochester Public Utilities

Additions to the Water

Rochester's water supply is of excellent quality due to the depth of the wells and the condition of the aquifers. The water could be consumed right from the ground as it is pumped out, with no treatment. However, Minnesota law requires that all municipal water systems add fluoride to drinking water to help prevent tooth decay. Fluoride levels are kept at an average concentration of 1.2 parts per million. To help assure this level, RPU performed over 3,200 fluoride tests around the City in 2012. Chlorine is added to kill bacteria that may be in the distribution system. The City tests 25 different sites each week in order to maintain an average chlorine level of 1.0 ppm. Polyphosphate (0.5ppm) is added to the water to help prevent corrosion and rusty colored water.

Even though the quality of the water supply is good today, the local geology presents risks for contamination. Where the underlying soils and bedrock are both permeable, the wells are vulnerable to pollution. The thicker and the less permeable the soil layer, the more the filtering capacity, reducing the risk for groundwater pollution.

Groundwater Vulnerability to Contamination



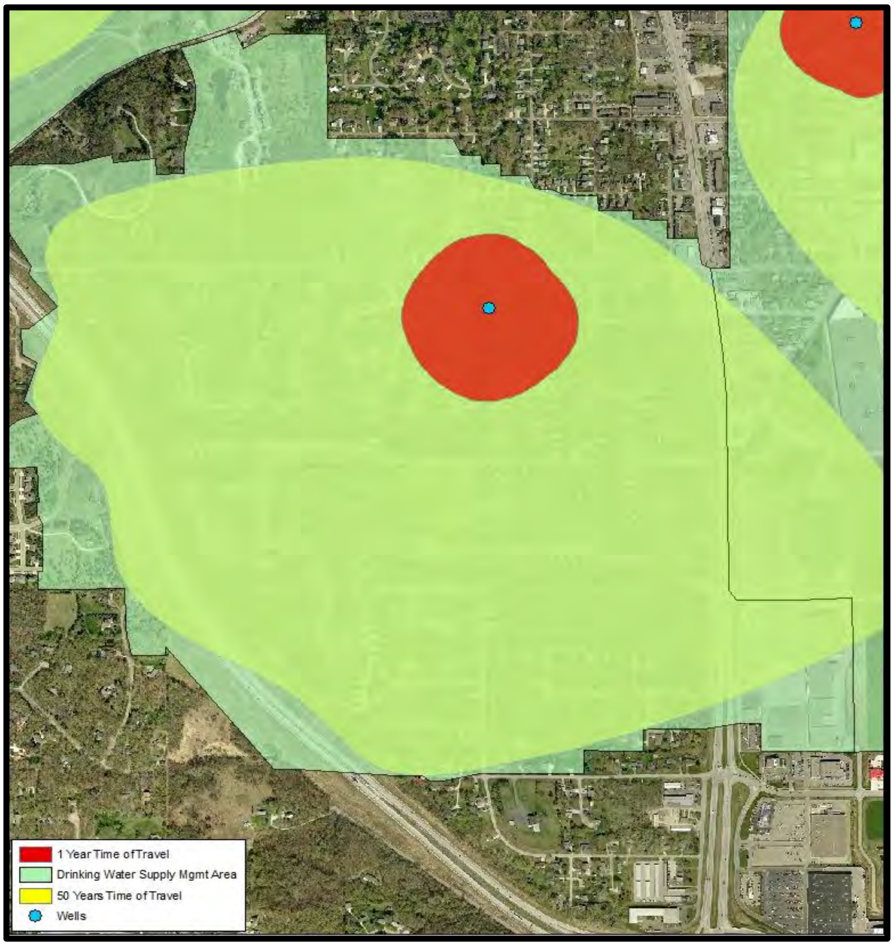
Source: RPU GIS

Wellhead protection

The Minnesota Department of Health administers the federal Safe Drinking Water Act in this state. One program related to this Act is the state's Wellhead Protection Program, which has a goal of preventing water supply pollution. Wellhead protection practices manage potential sources of contamination at the land surface inside the area where the well's water supply is extracted.

RPU has conducted computer modeling to determine how quickly surface pollutants would reach a well if a contaminant spilled or leaked on the land surface. The estimated rate of travel depends on factors, such as the type of soils and bedrock present, the depth and construction of the well, and the pumping rate of the well. A boundary line is drawn around the area within which it would take contaminants one year to travel; this area is called the "1 Year Time of Travel" zone or the "Emergency Response" zone. A similar "50 Year Time of Travel" zone is predicted; this is the wellhead protection area. A larger, "Drinking Water Supply Management Area" is created by using political boundaries that surround the wellhead protection area.

Wellhead Protection Area for a Well



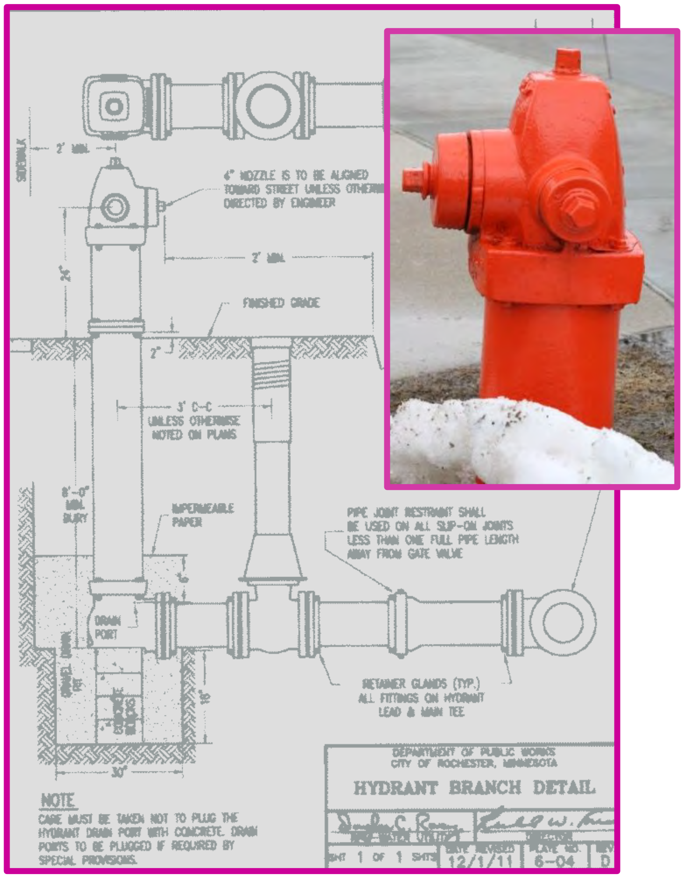
Source: RPU GIS data

Each operating municipal well must obtain a maintenance permit from the Minnesota Department of Health. When a decision is made to stop using a well, perhaps because it can no longer provide the amount of water needed, it must be sealed by a licensed contractor. This is an important step because an unused, or abandoned, well that is not sealed is an open channel between the land surface and the aquifer(s) into which the well was drilled. Surface water, contaminants, or improperly disposed of waste could then contaminate groundwater after entering the open drill shaft. Sealing eliminates the ground-to-surface aquifer connection and involves removing the pump, clearing the well of any debris, and filling it with concrete grout. Sealing is also required for private wells that are no longer in use.

Piping System

Water from the City's wells is pumped directly to homes and businesses through a series of interconnected underground pipes. At the end of 2012, Rochester had 573.6 miles of water pipes, also called mains, for distributing water. The distribution system also currently includes 14,903 valves used to shut off parts of the system when repairs are needed.

Fire hydrants are another important part of this underground plumbing system. Fire hydrants are used by the Rochester Fire Department to access water to fight fires. Hydrants are regularly flushed to help remove pipe residue from the water system. Rochester has 6,799 fire hydrants spread throughout the City.

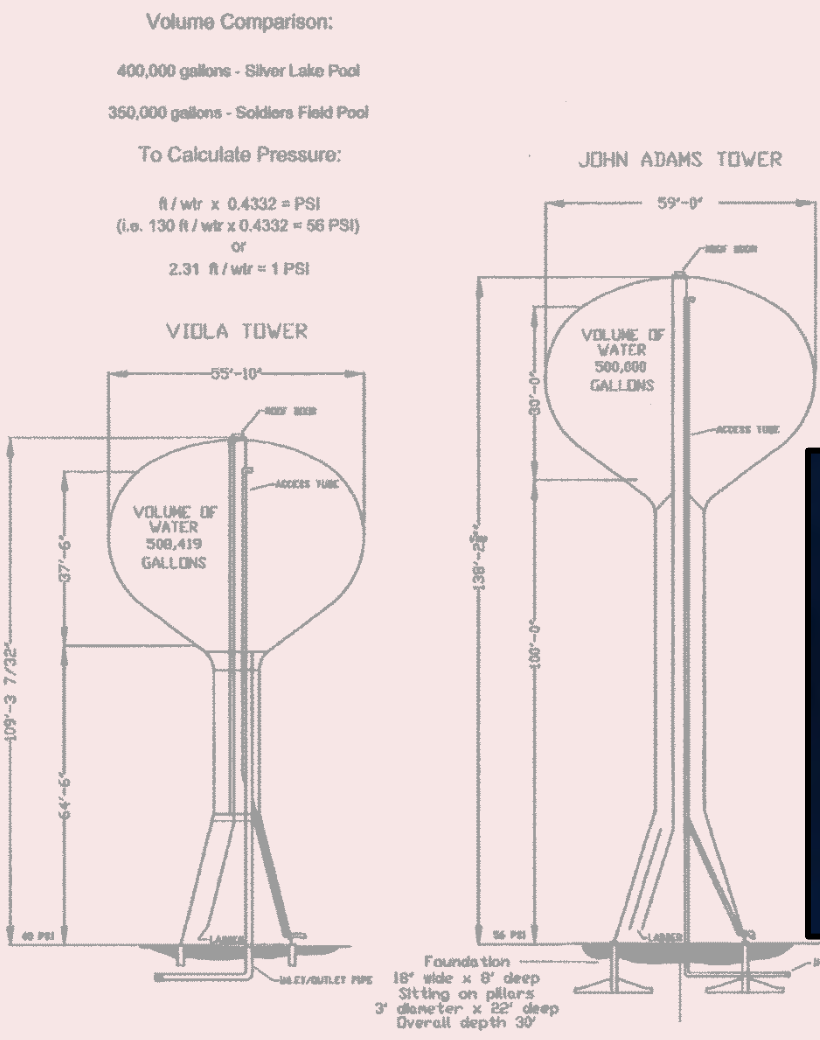


Source: Rochester Public Utilities

Water Storage Facilities

Water storage facilities help maintain the pressure needed to keep water flowing. These also store water that may be needed during times of high water usage, power outages, or for fighting fires. The pumps that move water into the facilities require energy, but the water storage facilities themselves use the force of gravity to move water back out. This creates a hydrostatic pressure on the water based on the height of the water column.

Water Tower Volume Comparisons



Source: Deb Las

Source: Rochester Public Utilities

A Water Tower Under Construction & the Inside of a Finished

Source: Rochester Public Utilities

Source: Deb Las

In addition to the familiar water towers, water storage facilities can take on other forms, such as a standpipe or a hydropillar. In a hydropillar, the top bell is where the water is stored. A maintenance pipe and electric lines usually run through the center. RPU collects a fee from companies that use the towers to support cell phone networks. Water can also be stored in underground reservoirs. Currently, there is a water storage reservoir underneath a parking lot on 4th Street SE, but this is programmed for removal in the near future, when a new water reservoir to serve downtown Rochester is built near St. Mary's Hospital.

Hydropillar

Source: Rochester Public Utilities

Saint Mary's Water Tower and Standpipe

Source: Rochester Public Utilities

Cool Fact: Water levels in water storage facilities are raised and lowered in the winter to keep the water from freezing.

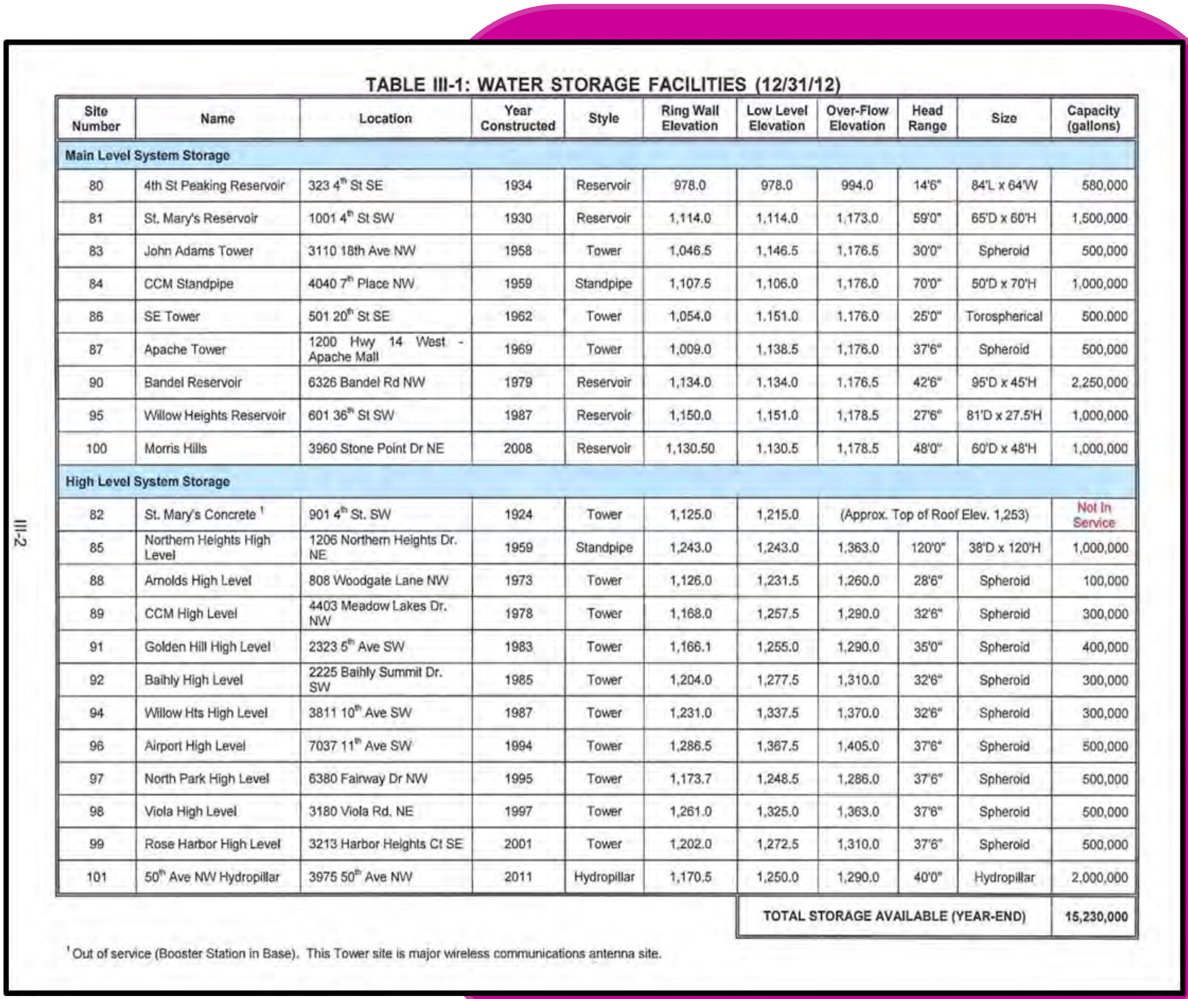


TABLE III-1: WATER STORAGE FACILITIES (12/31/12)

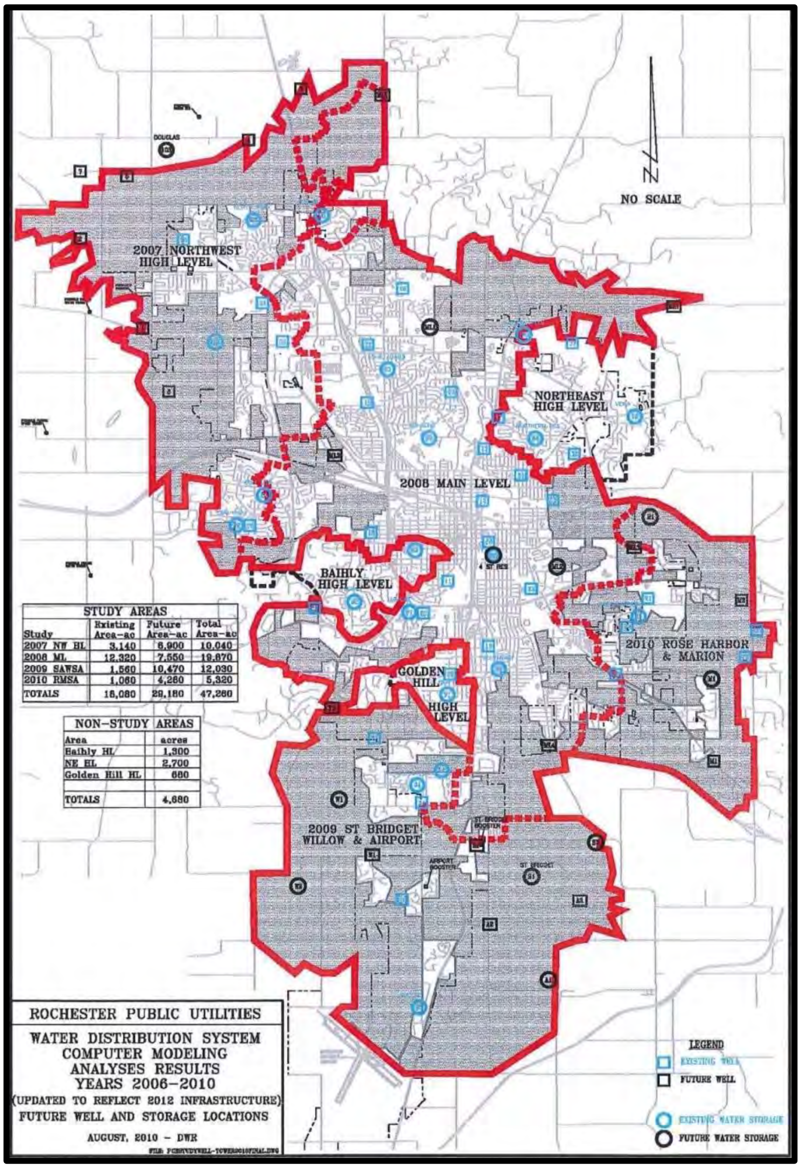
Site Number	Name	Location	Year Constructed	Style	Ring Wall Elevation	Low Level Elevation	Over-Flow Elevation	Head Range	Size	Capacity (gallons)
Main Level System Storage										
80	4th St Peaking Reservoir	323 4th St SE	1934	Reservoir	978.0	978.0	994.0	14'6"	84'L x 64'W	580,000
81	St. Mary's Reservoir	1001 4th St SW	1930	Reservoir	1,114.0	1,114.0	1,173.0	59'0"	65'D x 60'H	1,500,000
83	John Adams Tower	3110 18th Ave NW	1958	Tower	1,046.5	1,146.5	1,176.5	30'0"	Spheroid	500,000
84	CCM Standpipe	4040 7th Place NW	1959	Standpipe	1,107.5	1,106.0	1,176.0	70'0"	50'D x 70'H	1,000,000
86	SE Tower	501 20th St SE	1962	Tower	1,054.0	1,151.0	1,176.0	25'0"	Torospherical	500,000
87	Apache Tower	1200 Hwy 14 West - Apache Mall	1969	Tower	1,009.0	1,138.5	1,176.0	37'6"	Spheroid	500,000
90	Bandel Reservoir	6326 Bandel Rd NW	1979	Reservoir	1,134.0	1,134.0	1,176.5	42'6"	95'D x 45'H	2,250,000
95	Willow Heights Reservoir	601 36th St SW	1987	Reservoir	1,150.0	1,151.0	1,178.5	27'6"	81'D x 27.5'H	1,000,000
100	Morris Hills	3960 Stone Point Dr NE	2008	Reservoir	1,130.50	1,130.5	1,178.5	48'0"	60'D x 48'H	1,000,000
High Level System Storage										
82	St. Mary's Concrete [1]	901 4th St. SW	1924	Tower	1,125.0	1,215.0	(Approx. Top of Roof Elev. 1,253)			Not In Service
85	Northern Heights High Level	1206 Northern Heights Dr. NE	1959	Standpipe	1,243.0	1,243.0	1,363.0	120'0"	38'D x 120'H	1,000,000
88	Arnolds High Level	808 Woodgate Lane NW	1973	Tower	1,126.0	1,231.5	1,260.0	28'6"	Spheroid	100,000
89	CCM High Level	4403 Meadow Lakes Dr. NW	1978	Tower	1,168.0	1,257.5	1,290.0	32'6"	Spheroid	300,000
91	Golden Hill High Level	2323 5th Ave SW	1983	Tower	1,166.1	1,255.0	1,290.0	35'0"	Spheroid	400,000
92	Baihly High Level	2225 Baihly Summit Dr. SW	1985	Tower	1,204.0	1,277.5	1,310.0	32'6"	Spheroid	300,000
94	Willow Hts High Level	3811 10th Ave SW	1987	Tower	1,231.0	1,337.5	1,370.0	32'6"	Spheroid	300,000
96	Airport High Level	7037 11th Ave SW	1994	Tower	1,286.5	1,367.5	1,405.0	37'6"	Spheroid	500,000
97	North Park High Level	6380 Fairway Dr NW	1995	Tower	1,173.7	1,248.5	1,286.0	37'6"	Spheroid	500,000
98	Viola High Level	3180 Viola Rd. NE	1997	Tower	1,261.0	1,325.0	1,363.0	37'6"	Spheroid	500,000
99	Rose Harbor High Level	3213 Harbor Heights Ct SE	2001	Tower	1,202.0	1,272.5	1,310.0	37'6"	Spheroid	500,000
101	50th Ave NW Hydropillar	3975 50th Ave NW	2011	Hydropillar	1,170.5	1,250.0	1,290.0	40'0"	Hydropillar	2,000,000
						TOTAL STORAGE AVAILABLE (YEAR-END)				**15,230,000**

[1] Out of service (Booster Station in Base). This Tower site is major wireless communications antenna site.

III-2

Source: Rochester Public Utilities

As can be seen by the table above and the diagram on the following page, there are two water storage systems in Rochester, based on differences in ground surface elevation. This was developed because Rochester's downtown is at a lower elevation and it is surrounded by higher hills to the west, south, and east. These elevation differences create the need for the main level storage system (below 1,100 feet of elevation) and the high level system storage (above 1,100 feet of elevation). Having both a lower and an upper storage system helps maintain appropriate water pressure throughout the City.



STUDY AREAS			
Study	Existing Area–ac	Future Area–ac	Total Area–ac
2007 NW HL	3,140	6,900	10,040
2008 ML	12,320	7,550	19,870
2009 SAWSA	1,560	10,470	12,030
2010 RMSA	1,060	4,260	5,320
TOTALS	18,080	29,180	47,260

NON–STUDY AREAS	
Area	acres
Baihly HL	1,300
NE HL	2,700
Golden Hill HL	680
TOTALS	4,680

Source: Rochester Public Utilities

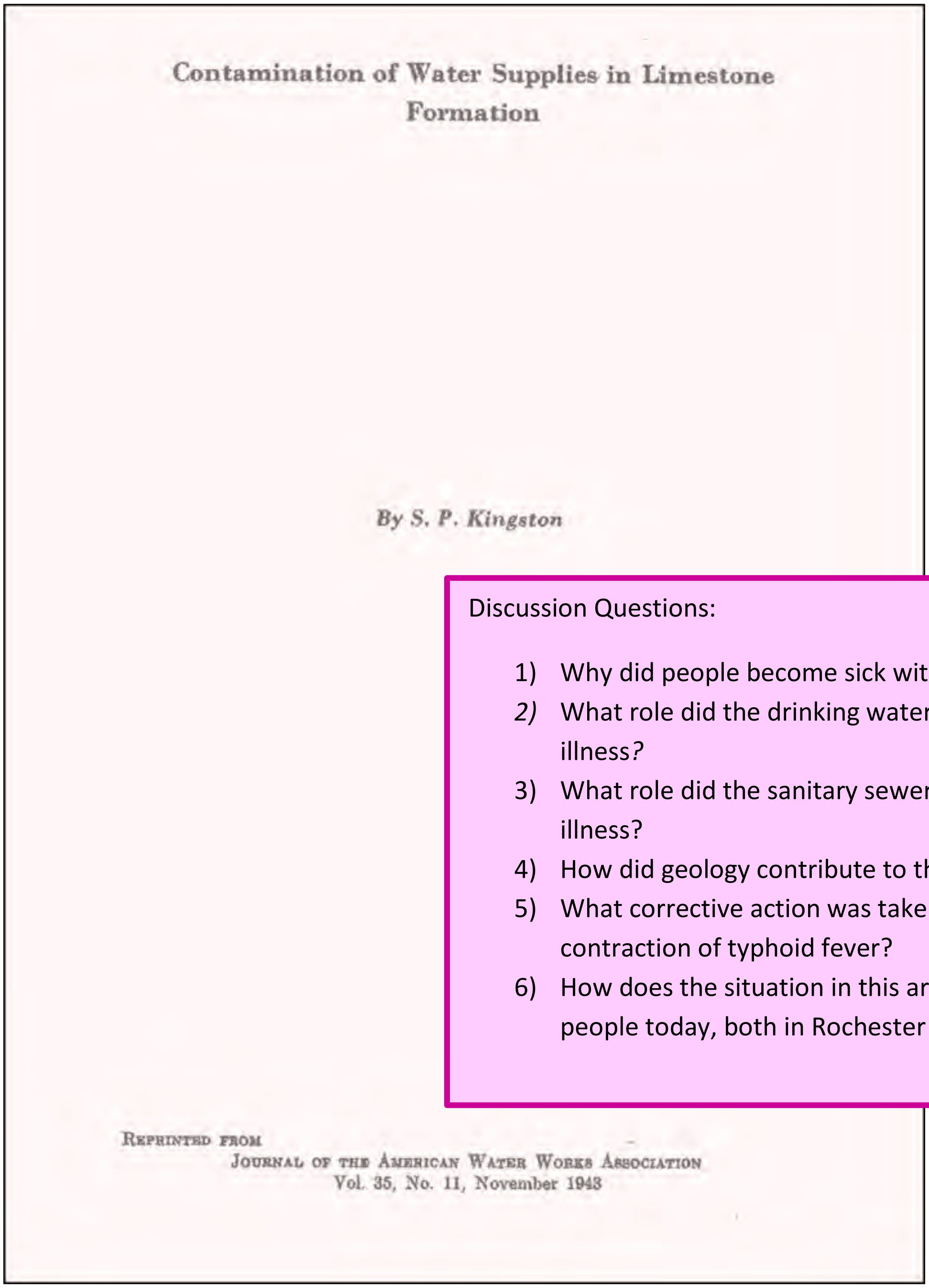
While Rochester's water supply is of very high quality, care must be taken to keep it that way. Two key federal agencies, the U. S. Environmental Protection Agency and the U. S. Food and Drug Administration, regulate the amount of allowable contaminants in natural drinking water and bottled water, respectively. Each year, RPU tests the water supply for many unwanted contaminants, including: radon, nitrate (as nitrogen), barium, chlorine, alpha emitters, combined radium, haloacetic acid, total trihalomethanes, and tetrachloroethylene. Tests done by the City verified that the amounts of these contaminants were below established regulatory thresholds. In 2012, over 1,200 water samples were also tested for fecal coliform and Escherichia coli (E. coli) bacteria. No fecal coliform or E. coli bacteria were found in the water samples.

RPU is required to publish an annual water quality report. The report for the current year and previous years can be found online at http://www.rpu.org/environment/water-quality/.

What water feature created Rochester's bowl-shaped topography?

Case Study: Contamination of Water Supply

Below is an article reprinted from the 1943 Journal of the American Water Works Association. It describes the typhoid fever outbreak that occurred in SE Minnesota in 1939-1940.



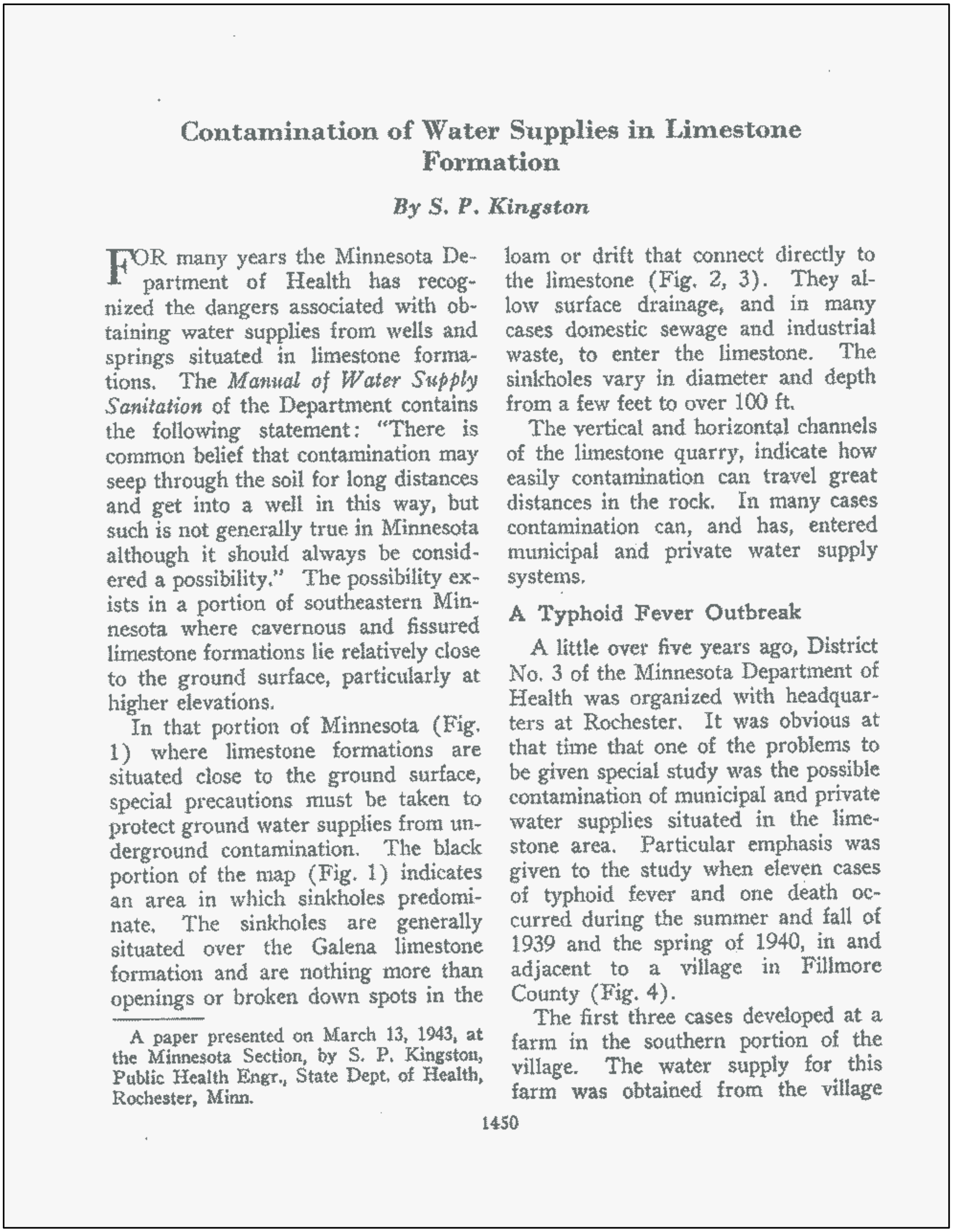
Contamination of Water Supplies in Limestone Formation

By S. P. Kingston

Reprinted from
Journal of the American Water Works Association
Vol. 35, No. 11, November 1943

Discussion Questions:

1) Why did people become sick with typhoid fever?
2) What role did the drinking water contribute to the illness?
3) What role did the sanitary sewer contribute to the illness?
4) How did geology contribute to the epidemic?
5) What corrective action was taken to prevent the future contraction of typhoid fever?
6) How does the situation in this article from 1943 relate to people today, both in Rochester and around the world?



Contamination of Water Supplies in Limestone Formation

By S. P. Kingston

FOR many years the Minnesota Department of Health has recognized the dangers associated with obtaining water supplies from wells and springs situated in limestone formations. The *Manual of Water Supply Sanitation* of the Department contains the following statement: "There is common belief that contamination may seep through the soil for long distances and get into a well in this way, but such is not generally true in Minnesota although it should always be considered a possibility." The possibility exists in a portion of southeastern Minnesota where cavernous and fissured limestone formations lie relatively close to the ground surface, particularly at higher elevations.

In that portion of Minnesota (Fig. 1) where limestone formations are situated close to the ground surface, special precautions must be taken to protect ground water supplies from underground contamination. The black portion of the map (Fig. 1) indicates an area in which sinkholes predominate. The sinkholes are generally situated over the Galena limestone formation and are nothing more than openings or broken down spots in the loam or drift that connect directly to the limestone (Fig. 2, 3). They allow surface drainage, and in many cases domestic sewage and industrial waste, to enter the limestone. The sinkholes vary in diameter and depth from a few feet to over 100 ft.

The vertical and horizontal channels of the limestone quarry, indicate how easily contamination can travel great distances in the rock. In many cases contamination can, and has, entered municipal and private water supply systems.

A Typhoid Fever Outbreak

A little over five years ago, District No. 3 of the Minnesota Department of Health was organized with headquarters at Rochester. It was obvious at that time that one of the problems to be given special study was the possible contamination of municipal and private water supplies situated in the limestone area. Particular emphasis was given to the study when eleven cases of typhoid fever and one death occurred during the summer and fall of 1939 and the spring of 1940, in and adjacent to a village in Fillmore County (Fig. 4).

The first three cases developed at a farm in the southern portion of the village. The water supply for this farm was obtained from the village

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A paper presented on March 13, 1943, at the Minnesota Section, by S. P. Kingston, Public Health Engr., State Dept. of Health, Rochester, Minn.

water supply system and from a drilled well situated on the farm. The farm well which may be designated as well "A" was apparently cased only to the first rock formation. This provided no protection from underground contamination.

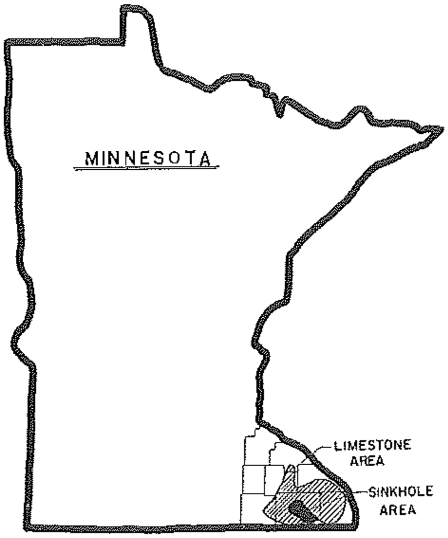


Fig. 1. Limestone and Sinkhole Area

A few weeks later five cases of typhoid fever occurred in the village. All of these persons had been using water supplied by the municipal system. The municipal supply is taken from two drilled wells which are designated as the old and new municipal wells. The old well is approximately 270 ft. deep and is cased only to the first rock formation. The new well is 1126 ft. deep and is cased to a depth of 400 ft. with 10-in. casing, to 340 ft. with 12-in. casing and to 20 ft. with 16-in. casing. All are cement-grouted in place for the purpose of excluding underground and surface contamination (Fig. 5).

In the spring of 1940, three more cases of typhoid fever occurred at a farm situated about two miles northwest of the village. The water supply for this farm was obtained from a drilled well cased only to the first rock formation. This well is designated as well "B" (Fig. 4).

At the time the typhoid fever cases occurred it was known that the village was discharging partly treated sewage into a sinkhole situated about 1500 ft. south of well "A" and 4000 ft. south of the municipal wells.

A complete epidemiological investigation disclosed no typhoid fever carriers with whom any of the cases had been in contact and no common vector other than the water supplies was found. However, the public health engineering work done in connection with the investigation revealed the following facts:

(a) Fluorescein dye (about three pounds) was introduced into the sinkhole receiving approximately 60,000 gpd. of partly treated sewage from the village. Periodic sampling was carried out at wells "A" and "B," and the two municipal wells. Within four hours the fluorescein dye appeared in water samples collected from well "A," a distance of approximately 1500 ft. from the sinkhole. However, no indica-

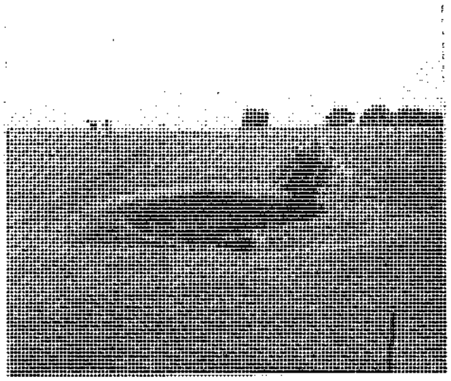


Fig. 2. Typical Sinkhole

tions of the dye were obtained from the samples of water collected from well "B" or the municipal wells. Bacteriological examination of water samples collected from well "A" showed a maximum concentration of 900,000 coliform organisms per 100 ml. as determined by the most probable number test.

(b) Just previous to the onset of the typhoid fever cases in the village, the old municipal well had been used during an emergency. All bacteriological samples collected from the old well, over a period of several months, contained coliform organisms with a maximum concentration of 1600 per 100 ml. At no time was any contamination found in the water obtained from the new municipal well.

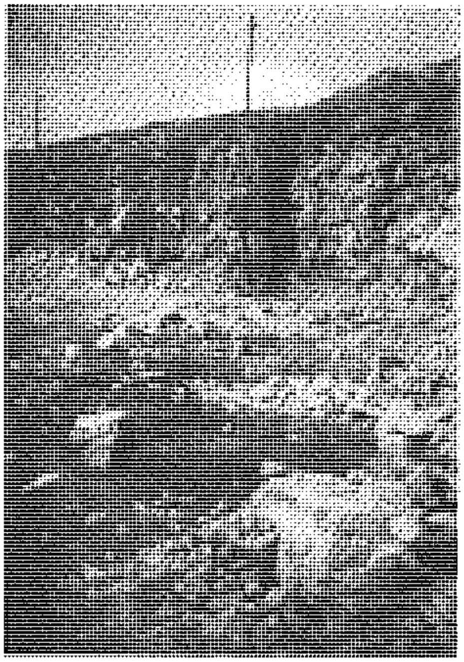


Fig. 3. Limestone Quarry

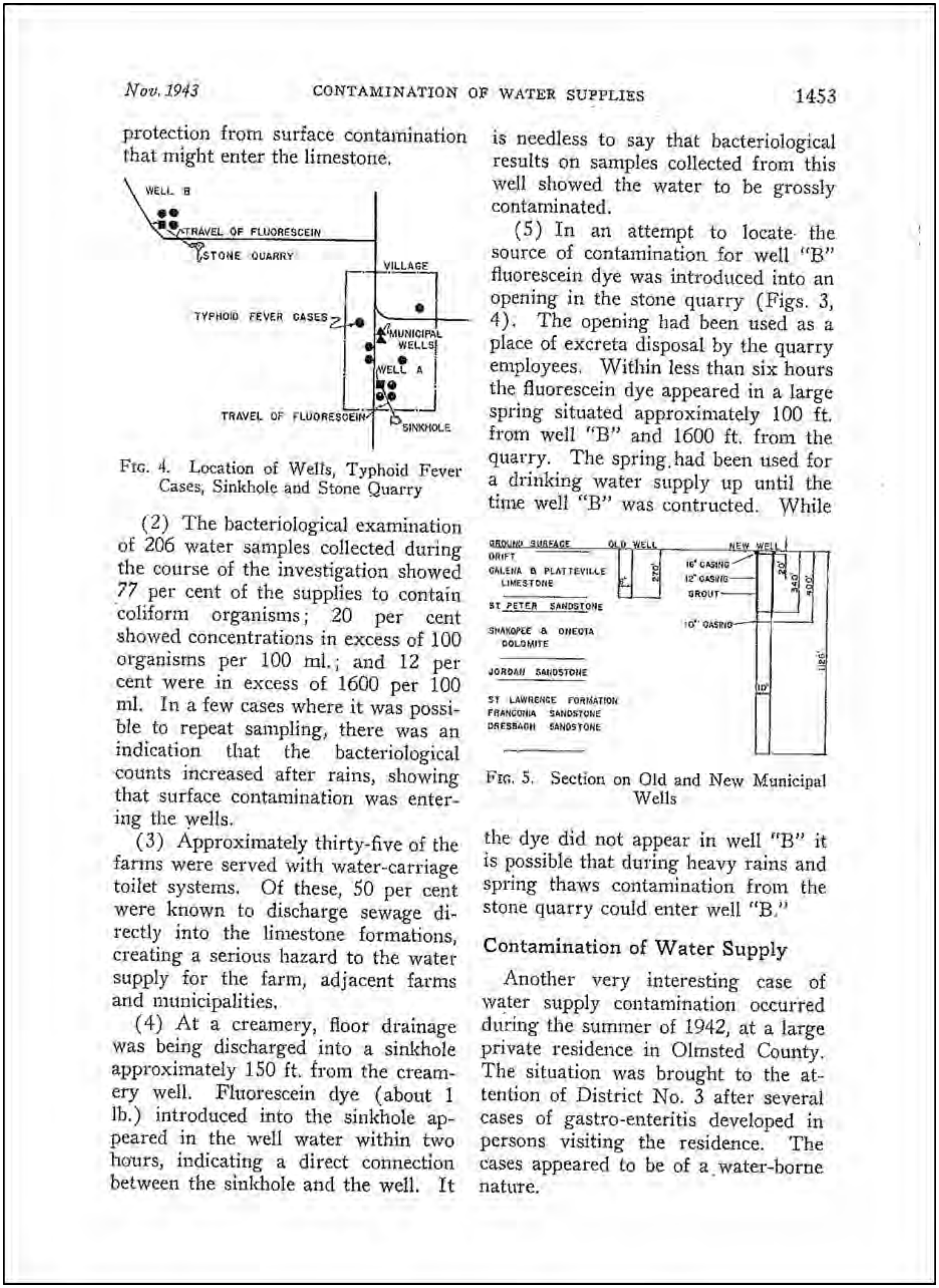
(c) Bacteriological examination of samples obtained from well "B" showed a maximum concentration of 92,000 organisms per 100 ml. In addition, typhoid organisms (*Eb. typhosis*) were isolated directly from 20-gal. water samples collected from the well. This indicated that excreta from a typhoid case or carrier were getting into the well. However, the investigation did not reveal the exact location at which domestic sewage was entering the limestone formations.

The foregoing engineering findings indicate that the eleven typhoid fever cases probably were water-borne and that infectious organisms had been transmitted through the cavernous and fissured limestone formations. Engineering recommendations were made to the municipality and to the individuals affected, as to methods of providing satisfactory water supplies and proper methods of sewage disposal.

Investigation of Farm Water Supplies and Sewerage Systems

The field work in connection with the typhoid fever outbreak, indicated the desirability of investigating a large number of farm water supplies and sewerage systems in the township immediately adjacent to the village. This investigation was conducted during the summer of 1941. The principal objects were to discover additional sources of contamination that may have contributed to the typhoid fever outbreak; and to collect engineering data on each water supply system. A total of 145 investigations were made at 130 farms. A summary of this investigation revealed the following:

(1) The major portion of all water supplies was poorly constructed above and below ground surface. Well casings in general were terminated at the first rock formation, thus providing no



protection from surface contamination that might enter the limestone.

FIG. 4. Location of Wells, Typhoid Fever Cases, Sinkhole and Stone Quarry

(2) The bacteriological examination of 206 water samples collected during the course of the investigation showed 77 per cent of the supplies to contain coliform organisms; 20 per cent showed concentrations in excess of 100 organisms per 100 ml.; and 12 per cent were in excess of 1600 per 100 ml. In a few cases where it was possible to repeat sampling, there was an indication that the bacteriological counts increased after rains, showing that surface contamination was entering the wells.

(3) Approximately thirty-five of the farms were served with water-carriage toilet systems. Of these, 50 per cent were known to discharge sewage directly into the limestone formations, creating a serious hazard to the water supply for the farm, adjacent farms and municipalities.

(4) At a creamery, floor drainage was being discharged into a sinkhole approximately 150 ft. from the creamery well. Fluorescein dye (about 1 lb.) introduced into the sinkhole appeared in the well water within two hours, indicating a direct connection between the sinkhole and the well. It is needless to say that bacteriological results on samples collected from this well showed the water to be grossly contaminated.

(5) In an attempt to locate the source of contamination for well "B" fluorescein dye was introduced into an opening in the stone quarry (Figs. 3, 4). The opening had been used as a place of excreta disposal by the quarry employees. Within less than six hours the fluorescein dye appeared in a large spring situated approximately 100 ft. from well "B" and 1600 ft. from the quarry. The spring had been used for a drinking water supply up until the time well "B" was contructed. While the dye did not appear in well "B" it is possible that during heavy rains and spring thaws contamination from the stone quarry could enter well "B."

FIG. 5. Section on Old and New Municipal Wells

Contamination of Water Supply

Another very interesting case of water supply contamination occurred during the summer of 1942, at a large private residence in Olmsted County. The situation was brought to the attention of District No. 3 after several cases of gastro-enteritis developed in persons visiting the residence. The cases appeared to be of a water-borne nature.

Plans and specifications for the residence, completed in the fall of 1941, showed the proposed location of the well and specified only that a certain amount of water per minute be obtained. No other well specifications were given. The well driller provided a 6-in. well 198 ft. in depth, cased only 8 ft. into the Platteville limestone, thus giving very little protection from underground contamination.

The plans indicated a septic tank and leaching pit situated approximately 110 ft. from the well. The plumber installed the septic tank in the creviced Platteville limestone and to provide a method for final disposal of the effluent a leaching pit was blasted in the rock (Fig. 6).

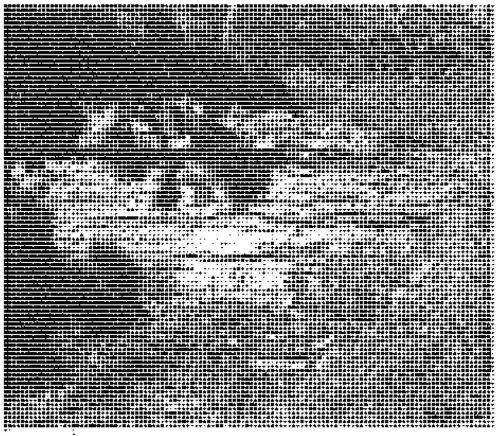


FIG. 6. Platteville Limestone

The engineering investigation revealed the water supply to have an odor of organic matter, indicating the probability of sewage contamination from the leaching pit. Again fluorescein dye was used. About one pound of the dye was introduced into the leaching pit and in less than fourteen hours the well water turned a deep green, indicating a direct connection between the leaching pit and the well (Fig. 7). This finding was substantiated by bacteriological results.

Immediate steps were taken to correct this situation. The use of this well was discontinued and a new drilled well was constructed (Fig. 8). The new well is 285 ft. deep and is cased with 8-in. casing to a depth of 145 ft. The 8-in. well casing was placed in a 16-in. drill hole and the annular space between the casing and the drill hole was filled with cement grout. A cast-iron sewer was provided for the effluent from the septic tank and a soil absorption system constructed in suitable soil about 250 ft. from the well. When all construction work was completed on the new well and sewerage system, the old well was filled with concrete and the old leaching pit filled with clay.

Contamination of Municipal Water Supply

The investigation of the contamination of water supplies situated in the limestone area, of course, included all of the municipal water supplies. Most of the municipal water supplies are obtained from deep wells but a few large springs are used. The springs are apparently subject to surface drainage through sinkholes, etc. This occurs during periods of heavy precipitation and spring thaws when the water becomes turbid and the concentration of coliform organisms increases. One very large spring, although not used for a municipal water supply, is clear during normal weather conditions but during periods of heavy rains becomes extremely turbid and occasionally straw and corncobs appear in the water, indicating a direct connection to the ground surface.

In the spring of 1942 during an investigation made of a municipal water supply derived from a typical limestone spring, it was reported that there had been several cases of gastro-enteritis during the preceding month, particularly during a period when the water had been turbid.

To confirm these reports a survey was made by visiting every fifth household in systematically selected sections of the village to determine the incidence of gastro-enteritis during the preceding month. Seventy-two households were visited and information obtained from 274 persons, or approximately 13 per cent of the population. The survey indicated that an outbreak of gastro-enteritis affected approximately 10 per cent of the population during a thirty-day period. Many of the individuals questioned associated their illness with the time when the water supply was turbid and unsatisfactory for domestic use.

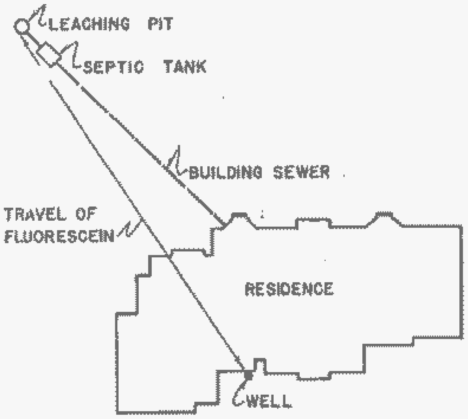


FIG. 7. Location of Well and Leaching Pit at Private Residence

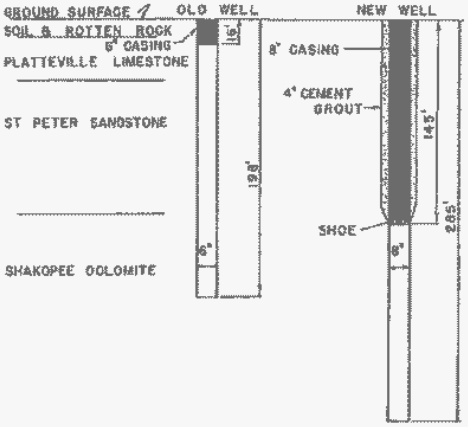


FIG. 8. Section of Old and New Wells at Private Residence

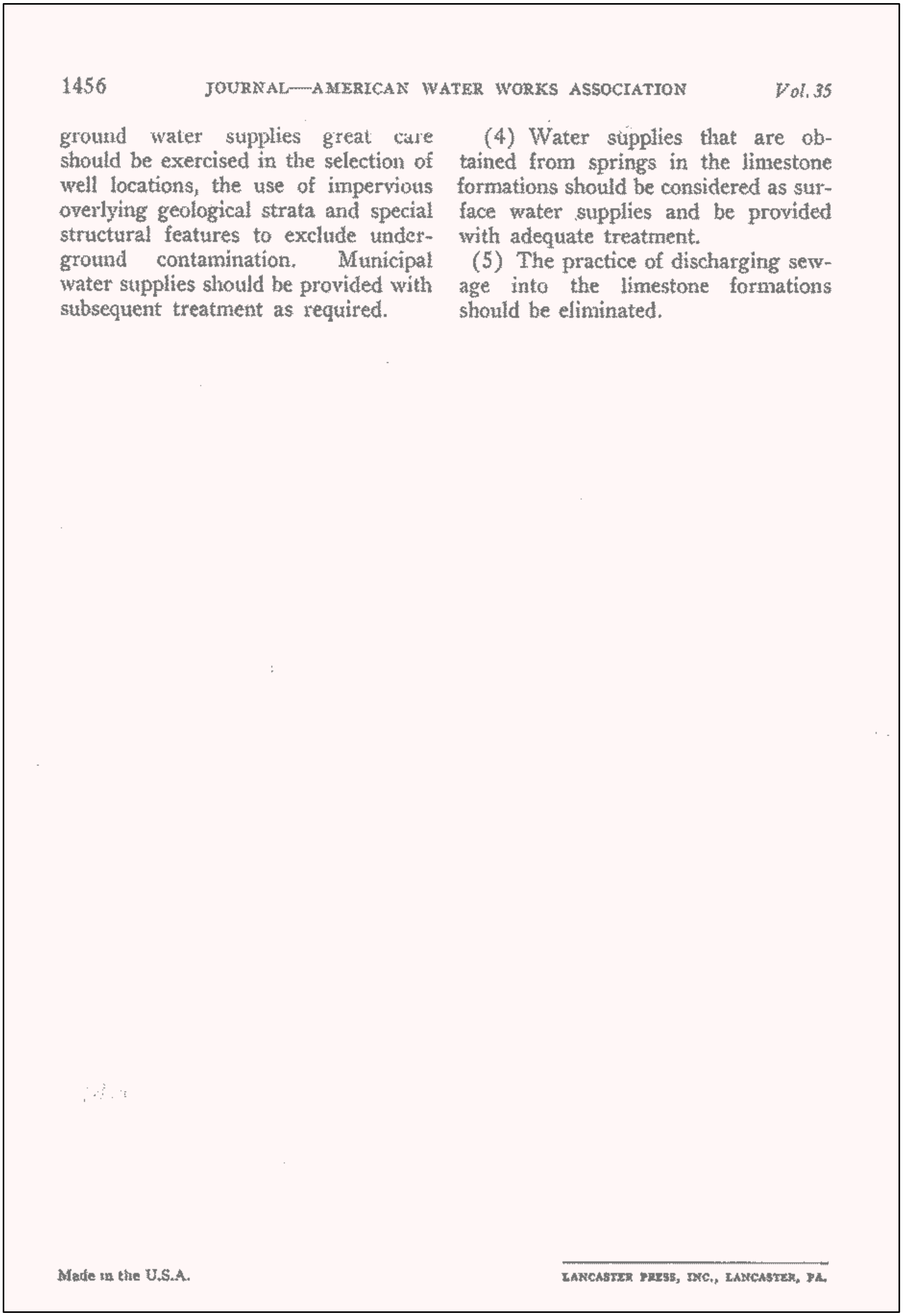
Summary

The main purpose of this report has been to discuss some definite instances where municipal and private water supplies obtained from limestone formations, have been seriously contaminated, and not to propose any detailed methods of correction. However, it is probably advisable to summarize the more salient features and to formulate broad corrective measures as follows:

(1) It is obvious that there is real danger of underground contamination of municipal and private water supplies situated in the fissured and cavernous limestone area of southeastern Minnesota. This is borne out by the fact that on four separate occasions underground sewage flow was traced, with the aid of fluorescein dye, up to a maximum distance of 2000 ft. and in every case the dye was recovered from a water supply that had been used for drinking purposes. In connection with a typhoid fever outbreak it was possible to isolate pathogenic organisms (*Eb. typhosis*) directly from a well water supply.

(2) A very large portion of farm or private water supplies are of unsatisfactory construction and are further endangered by the practice of discharging sewage directly into the limestone formations.

(3) In the development of under-



ground water supplies great care should be exercised in the selection of well locations, the use of impervious overlying geological strata and special structural features to exclude underground contamination. Municipal water supplies should be provided with subsequent treatment as required.

(4) Water supplies that are obtained from springs in the limestone formations should be considered as surface water supplies and be provided with adequate treatment.

(5) The practice of discharging sewage into the limestone formations should be eliminated.

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