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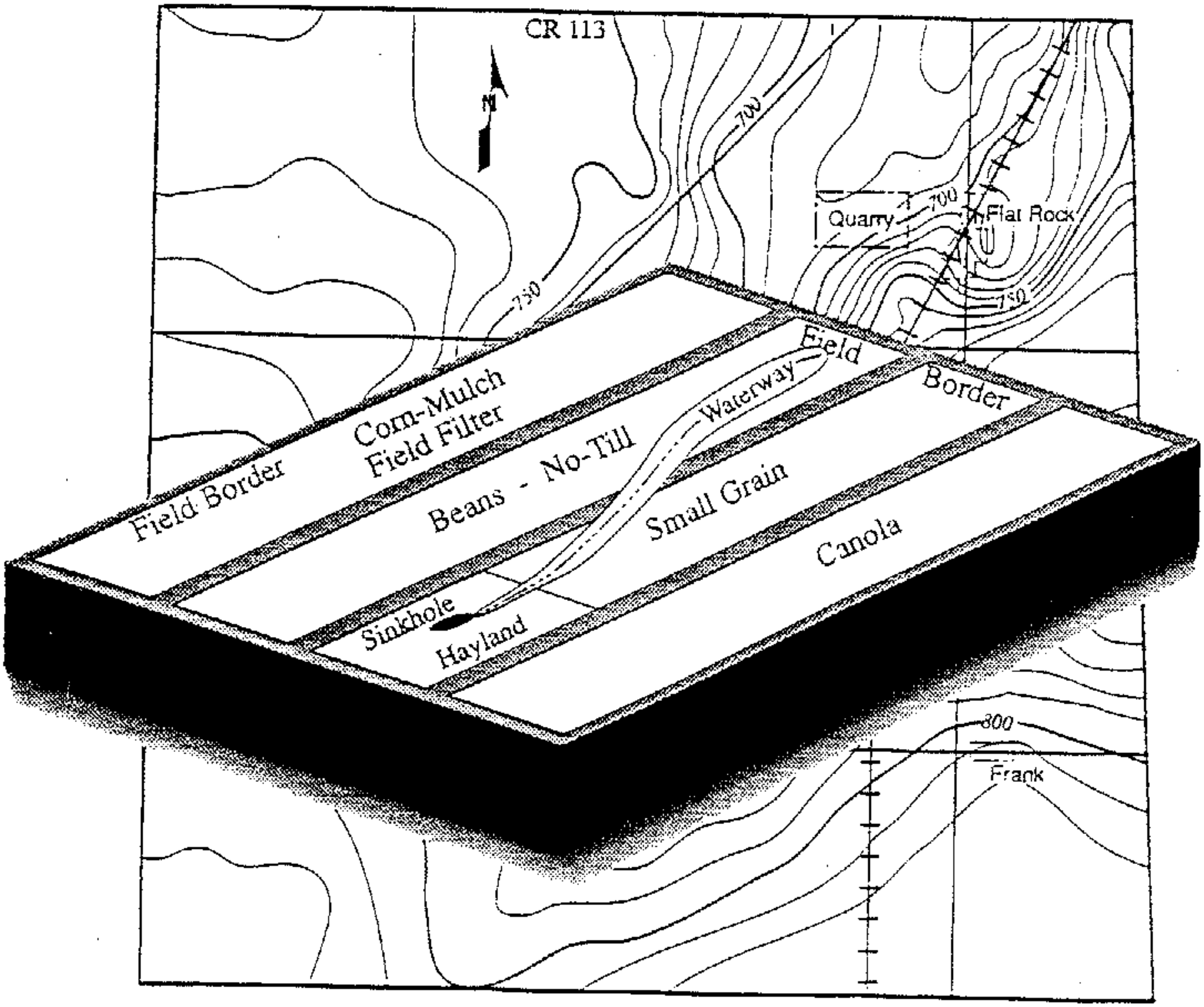

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March 1994

IMPACT OF BEST MANAGEMENT PRACTICES ON SURFACE RUNOFF AND GROUND WATER QUALITY IN A SOLUTIONED LIMESTONE AREA THOMPSON TOWNSHIP, SENECA COUNTY, OHIO

by

James Raab, Wayne Jones, Rebecca Petty, and Mike Angle
Ohio Department of Natural Resources
Division of Water

Jamie Kreglow, Mark Zimmerman, and Ada Walton
Seneca County Soil and Water Conservation District

and
Lawrence A. Drane III and Russell J. Kocher
University of Toledo

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Chapter 1. INTRODUCTION

In March, 1990, the Seneca Soil and Water Conservation District, Cooperative Extension Service, Seneca County Board of Health, and the Ohio Farm Bureau sponsored a county-wide well water testing program. There were 87 residents of Thompson Township who voluntarily paid to have their wells tested for nitrates and 85 residents paid to have a bacteria test performed by the Seneca County Health Department. The samples were analyzed by the Heidelberg Water Quality Lab primarily for nitrates, and Aqua Tech of Melmore analyzed for bacteria.

The average nitrate level for Thompson Township was 3.8 milligrams/liter (mg/l) compared to 1.67 mg/l average for the county. Eleven of these wells (12.6%) exceeded the safe drinking water standard of 10 mg/l. The highest nitrate concentration was 16.9 mg/l. Twenty wells had 0 - 0.3 mg/l nitrates, 31 wells had 0.3 - 3.0 mg/l, and 25 wells had 3.0 - 10 mg/l nitrates.

Of the 85 bacteria samples taken, 30 (35.3%) were bacteriologically unsafe. The acceptable safe water limits are less than 4 ppm for coliform bacteria.

High bacteria and nitrate concentrations have been found in a large percentage of the wells in the area, creating the need for a sewage system moratorium. This moratorium does not allow present landowners to build homes in the area, unless the septic system perimeter tiles can outlet directly into an open flowing stream. Many Thompson Township residents are concerned, and wonder what needs to be done to lift the moratorium and allow the present residents to have clean usable well water.

The main cause for the poor water quality is the more than 250 sinkholes that are mapped throughout the township (SCS, 1980). These sinkholes allow the direct recharge of the ground water supply by surface water. Faulty or substandard septic systems and runoff containing fertilizers and pesticides from adjacent agricultural fields drain into these sinkholes.

In order to improve both surface and ground water quality, the Seneca Soil and Water Conservation District, Ohio Department of Natural Resources - Division of Water, Soil Conservation Service, Seneca County Health Department, and the University of Toledo have joined forces to implement a USEPA Section 319 grant focusing on the use of Best Management Practices (BMP) in karst (solutioned) limestone areas.

The main goal of the project was to reduce non-point source pollutants affecting ground water quality in Thompson Township. Objectives to meet this goal were :

- Initiate a water quality education program that reaches all residents of the study area and promotes NPS pollution control.
- Determine the hydrogeology of the study area so that proper ground water sampling points can be determined.
- Monitor and document water quality improvement as the result of project implementation.
- Reduce sediment load and NPS pollutants flowing into sinkholes and entering the ground water system by promoting and installing BMPs.

Chapter 2. GEOLOGIC FRAMEWORK

2.1 Location and Physiography

Thompson Township is located in northeast Seneca County and is known for its farming industry and limestone quarry. Thompson Township is bordered by Sandusky County to the North and to the east by Huron County (see Figure 1). Reed Township and Adams Township of Seneca County lie to the south and west of Thompson Township, respectively.

Thompson Township is located in the Till Plains Region of the Central Lowlands Physiographic Province (Fenneman, 1938). Eighty-nine percent of the study area is covered by the Blount-Pandora and Glynwood-Blount Soil Associations. These soil associations are nearly level to gently sloped, poorly to moderately well drained, and were formed from moderately fine textured glacial till (USDA, Soil Conservation Service, 1980). The low relief and the presence of numerous sinkholes in Thompson Township inhibits the formation of efficient surface drainage. The main drainage channels in Thompson Township are Royer Ditch and Schneider Ditch. Royer Ditch is located within the Lower portion of the Sandusky River Basin and drains the western 2/3 of Thompson Township. The eastern 1/3 of the township lies within the Pickerel Creek-Pipe Creek Basin. Schneider Ditch drains entirely into a series of sinkholes and Royer Ditch contains sinkholes along its path that are sometimes open to direct ground water recharge. Therefore, much of the precipitation that falls within Thompson Township subsequently recharges the ground water system via the large number of sinkholes that have formed in the limestone bedrock.

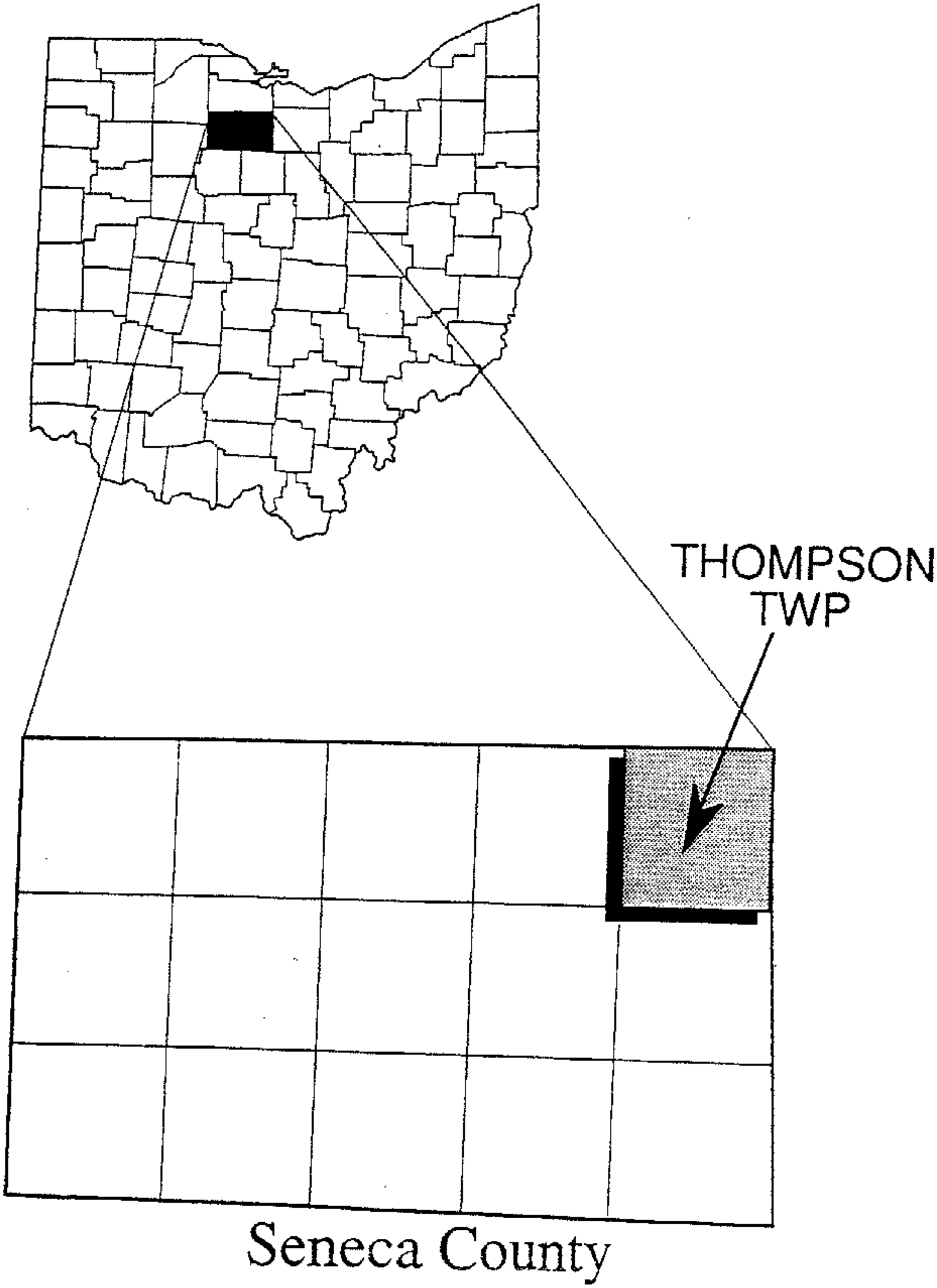


Figure 1. Location of the Study Area

2.2 Bedrock Geology

The bedrock underlying Thompson Township is primarily Silurian and Devonian Age limestones and dolomites. Table 1 is a stratigraphic column depicting the different rock units present below Thompson Township. These units, which are approximately 665 feet thick, are the regional aquifer for West Central, Northwest, and North Central Ohio. Rocks that are exposed at the Flat Rock quarry and near sinkholes within Thompson Township are of Devonian Age and consist of, from youngest to oldest, the Delaware, Columbus, and Lucas Formations. The outcrop area of the Columbus and Delaware Formations is illustrated in Figure 2.

The youngest rocks are exposed to the east because this area lies on the eastern flank of the Findlay Arch. The Findlay Arch is a part of the regional structural high that separates the Appalachian, Michigan, and Illinois Basins. The rocks within Thompson Township dip southeastward into the Appalachian Basin at approximately 30 feet per mile.

The Lucas and Columbus Formations are part of the Detroit River Group, which lies unconformably over the Bass Islands Group. The Lucas Formation is a thin bedded, light blue to brown dolomite. Due to its thin bedded nature and joint features, the Lucas is capable of yielding upwards of 100 gallons per minute (gpm) (Schmidt, 1982).

The Columbus Formation ranges from a limey dolomite at its base to a limestone at the top. It varies in color from light gray to light brown, is massively bedded and contains some layers and nodules of chert. The Columbus Formation is of very pure composition, averaging 94 percent calcium carbonate, which makes it susceptible to the development of karst features such as sinkholes and caverns. Seneca Caverns, located within Thompson Township, is developed within the Columbus and Lucas Formations. Secondary porosity, caused by the fractures and enhanced by dissolutioning, makes the Columbus Formation a good aquifer. Yields from wells penetrating the entire Columbus Formation may exceed 100 gpm (Schmidt, 1982, ODNR-Division of Water, 1970).

The youngest of the Devonian carbonates located within Thompson Township is the Delaware Formation. The Delaware Formation is predominantly limestone with some interbedded shale layers (Stout, 1941). This unit, which is much harder and denser than the Columbus Formation, does not produce much ground water. Yields from wells completed in the Delaware Formation typically are less than 5 gpm.

Table 1. Stratigraphic Column For Northeastern Seneca County

SYSTEM	SERIES	GROUP	FORMATION	ROCK TYPE
QUATERNARY	Pleistocene	Wisconsin		
		Pre–Wisconsin		
DEVONIAN	Erian		Delaware	Limestone
	Ulsterian		Columbus	Limestone/Dolomite
			Lucas	
			Amhurstburg	
SILURIAN	Cayugan	Salina	F Unit	Interbedded sequences of Anhydrite and Dolomite
			E Unit	
			C Unit	
			B Unit	
			A_2 Unit	Dolomite
			Tymochtee & Greenfield	
	Niagaran	Lockport	Lockport	Dolomite

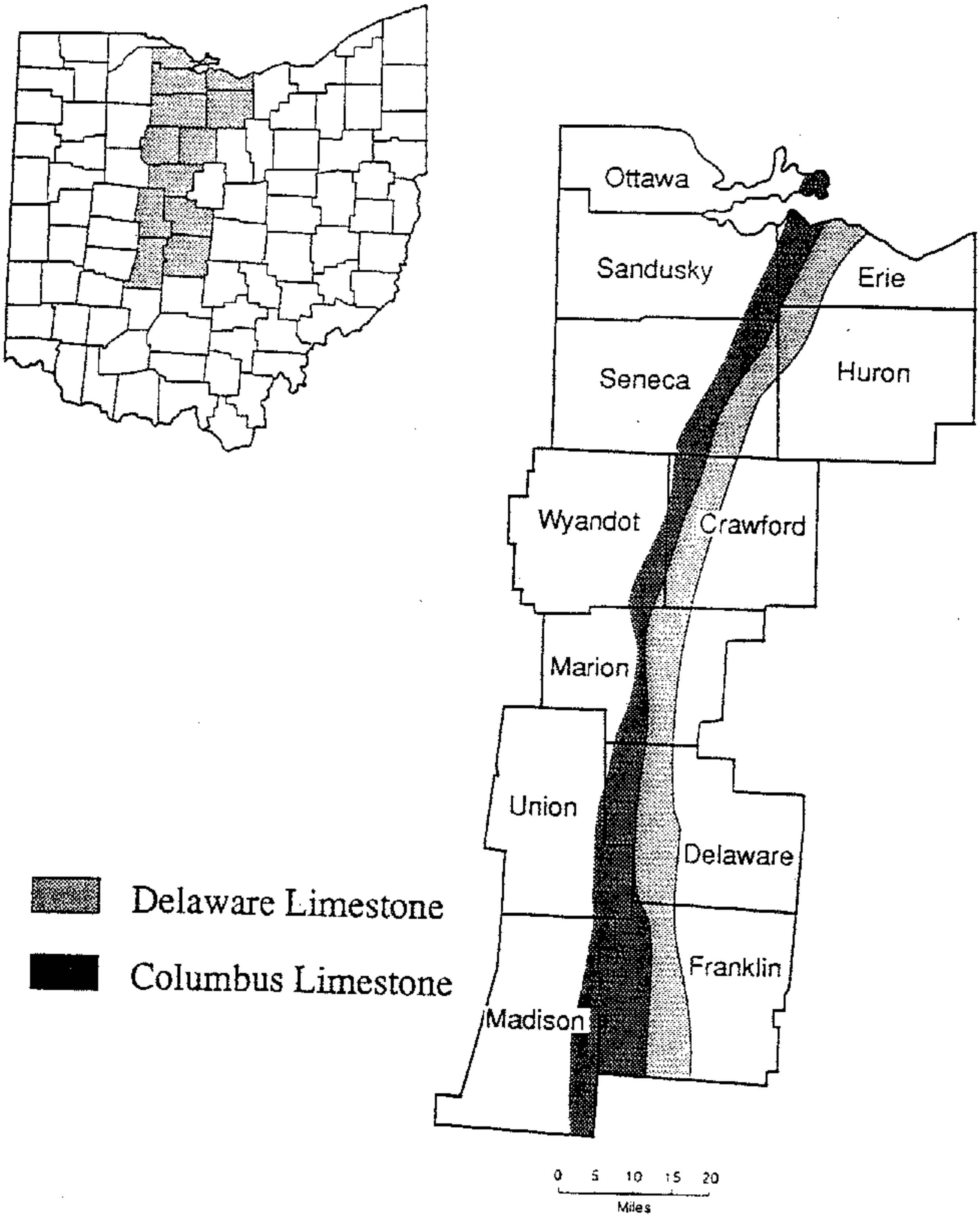


Figure 2. Location of Delaware and Columbus Limestone Outcrops.
Modified from Janssens, 1970.

2.3 Glacial Geology

Several episodes of ice advance covered northeastern Seneca County during the Pleistocene Epoch (10,000-1 million Years Before Present (Y.B.P.)). The surficial deposits primarily reflect the last ice advance; the Wisconsinan (approximately 10,000-60,000 Y.B.P.). Evidence of earlier ice advances has either been eroded away or lies at depth below the surface.

The thickness of the glacial deposits or drift varies from less than 5 feet in the vicinity of Flat Rock to over 35 feet in the far south central portion of Thompson Township (see Figure 3). The drift is composed primarily of glacial till. Till is an unsorted, highly variable mix of silt, clay, sand and gravel deposited directly by ice sheets. Thin, discontinuous sand and gravel lenses are commonly found within glacial till. The till in Thompson Township has been identified as clay and silt-rich Hayesville Till and Hiram Till by Fernandez (1988) and Echelbarger (1978). Fernandez speculated that some of the hummocky knob and kettle terrain was due to ablation or melting of the ice sheets. The till cover also mimics the sinkholes in the bedrock surface which further enhances the rolling topography. The ablational terrain is found south of Fireside.

Large ancestral lakes of Lake Erie occupied the Erie basin after the melting of the ice sheets. These lakes flourished between 12,000-14,000 Y.B.P. The wave action of these lakes probably helped to erode away much of the till deposited in the area. Bedrock highs in the Flat Rock area would have been islands and sand bars at this time. These lakes left prominent beach ridges and deltas throughout much of Northwestern Ohio. The beach ridges are composed of well sorted, clean sand and fine gravel. Dunes composed of fine sand commonly overlie the beach ridges. The beach ridges and dunes are much more permeable then the underlying dense, fine-grained till. The beach ridges associated with ancestral Lake Maumee are found at common elevations of 770-775 feet and 795-800 feet mean sea level (msl).

The lower elevation ridge extends from Castalia through Bellevue to Tiffin and then extends westward toward Findlay (Forsythe, 1959, 1973). State Route 101 roughly follows the trend of this particular ridge. The higher elevation Maumee beach ridge wraps around the town of Flat Rock and roughly follows the Sandusky County-Seneca County border. This beach ridge is much more difficult to trace and the deposits are thinner. Fernandez and Pavey (pers. comm.) have also speculated that thin isolated beach deposits may be found at elevations up to 820 feet. These deposits have not been formally named.

During precipitation events, water tends to quickly percolate through the beaches and dunes and temporarily perches on the less

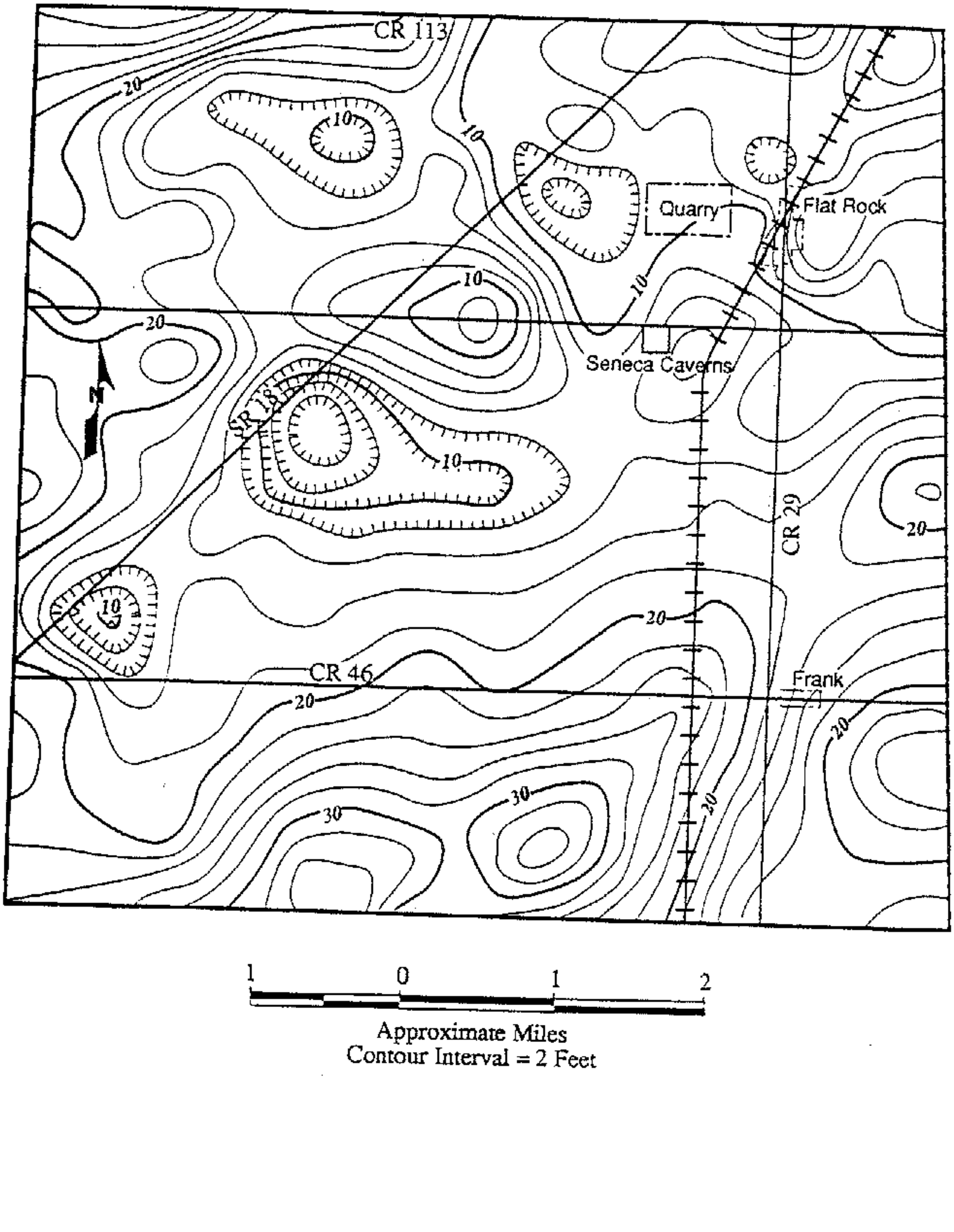


Figure 3. Drift Thickness Map of Thompson Township.
Map was constructed from 134 well logs.
(Modified from Drane, 1993)

permeable till. This water tends to flow towards the nearest stream or sinkhole. The isolated sand and gravel lenses within the till are typically too thin and near the surface to serve as a viable aquifer. In areas where the sandy beach ridges directly overlie the bedrock, precipitation quickly infiltrates into the limestone and recharges the aquifer.

Generally, till is relatively dense, fine-grained and impermeable and does not constitute an aquifer. Till is considered to be an aquitard in many places, including Thompson Township, impeding recharge to the aquifer. However, the upper 10-15 feet of the till is generally very weathered and typically contains fractures (Angle, 1988, Strobel, 1993). Water tends to pass downward through weathered tills along these fractures. This allows for greater recharge through the till than what might be expected. This is an important factor in much of Thompson Township as the till cover is often less than 15 feet thick.

Chapter 3. PREVIOUS STUDIES

3.1 Geologic Related Studies

Karst geology has been studied throughout the United States and the world for hundreds of years. Areas of extensive karst in the world is estimated to be 7 to 10 percent of the land area (Ford and Williams, 1989). Twenty-five percent of the global population is supplied largely or entirely by karst waters (Ford and Williams, 1989). Carbonate rocks, which form the karst features, are more abundant in the northern hemisphere. Major karst areas in the United States are the Mammoth Cave region (Kentucky, Tennessee), the Interior Plateau (Missouri, Iowa, Minnesota), Carlsbad Caverns (New Mexico), Florida, and isolated areas of the Rockies and Cascade Mountain Ranges. Karst features are not as widespread or extensive in Ohio compared to the above mentioned sites, however, it is developed enough to warrant further studying to improve ground water quality in north-central Ohio.

Very few hydrogeological studies have been conducted near the Thompson Township site. The lack of surface drainage was first noticed in the early 1800's. To take advantage of the potential energy generated by water flowing into fracture openings, sinking streams were utilized to run sawmills. In 1928, Hubbard postulated that the sinkholes and conduits in the limestone were due to solutioning of the limestone and enlargement of the existing fractures. Ver Steeg and Yunck (1932) discussed the existence of sinkhole development and artesian springs in the Castalia area. They determined that the sinkholes were formed by the extensive development of an underground drainage system which caused the surface rocks to slump, forming caverns.

Bacterial contamination of ground water in the Bellevue area was first noted by Daugherty in 1941. Further studies by the Ohio Department of Natural Resources, Division of Water (1961) again documented the ground water contamination and mapped its extent. The installation of a central sewer system in Bellevue in the early 1970's eliminated a large percentage of sewage effluent from entering the ground water system, thus improving ground water quality (Sikora, 1975).

In 1988, Gary Kihn, of the University of Toledo, completed his Master's thesis of the hydrogeology of the Bellevue-Castalia Area. Kihn conducted a dye trace experiment north of Bellevue to trace ground water flow towards Castalia. Unfortunately, no dye was detected at any of the springs that were monitored. This dye trace indicated that either the amount of void space within the bedrock was greater than expected, the aquifer was acting to store water rather than transmit it, the sinkhole where the dye was injected may be feeding a local flow system, or the dye may be moving along a deeper flow path and may be discharging at points that were not monitored. Whatever the reason, this dye trace experiment indicated that a larger amount of dye would be needed in future dye trace experiments in this area.

In 1993, Lawrence A. Drane III, of the University of Toledo, completed his Master's thesis that covered the hydrogeology and geophysics of karst terrain in Thompson Township. In addition to assisting in this NPS project, Lawrence conducted geophysical surveys within Thompson Township to determine the existence and orientation of voids in the subsurface. Various geophysical techniques were used that indicated that a major void exists trending northeast from the center of Thompson Township to the north and into Sandusky County.

As part of the mapping programs at the ODNR, Division of Water, the ground water availability map (Schmidt, 1982) and the pollution potential map (Smith, K., in production) were produced for Seneca County. The ground water resources map indicates that the Lucas and Columbus Limestones are capable of yielding over 100 gpm to wells that encounter fractures or voids. Ground water yields from the Delaware Limestone, found in the extreme eastern and southeastern portions of Thompson Township are typically less than 3 gpm.

The pollution potential map was produced using the DRASTIC method developed by Aller et. al. (1987) for the USEPA. This system rates an aquifer's potential for contamination from land surface activities. From this map, it is shown that Thompson Township has the highest aquifer vulnerability ratings in the county. These ratings would have been even higher if the depth to water was less. Depth to water is weighted very high in the DRASTIC system, therefore wells with deep static water levels receive generally low DRASTIC ratings. The high amount of ground water recharge helped to offset the lower depth to water rating for an overall highly vulnerable rating.

3.2 BMP Related Studies

In 1981, the Iowa Department of Natural Resources began a research project referred to as the Big Spring Basin Demonstration Project. This project was designed to investigate the relationship between agricultural activities and ground water quality problems in a karst region in Northeast Iowa. This area has very similar geologic conditions and land use as Thompson Township. The overall objective of the program is to develop intensive interactive farm demonstrations and public education program to help farmers implement improved management practices. The major goal of this project was to assist farmers to improve their efficiency and profitability while reducing impacts on the environment: from soil erosion, chemical and nutrient contamination of water supplies and consumption of non-renewable resources. Numerous reports and updates on water quality impacts are being published (Halberg et. al., 1984, 1985, 1986, 1987, 1988, Libra, et. al., 1986, 1987, 1991, Littke and Halberg, 1991).

Numerous other studies have been conducted on the effectiveness of BMPs to improve both surface and ground water quality. The Alliance for a Clean Rural Environment (ACRE) has published a fact sheet titled "Sinkhole Management Protects Groundwater". This fact sheet stresses the importance of sinkhole maintenance and properly managing stormwater flow in an area of sinkhole development.

Best management practices that are effective in sinkhole areas are field border strips, sinkhole structures, hayland plantings around sinkhole structures, grassed waterways, and field filter strips. Other BMPs that would be effective under most geologic conditions are winter cover crops, no-till farming, sediment control basins. Table 2 lists the BMPs and criteria for installation used along with cost share and maximum acreage available for karst areas and for this non-point source project.

Table 2. Cost share practices available with associated eligibility criteria.

PRACTICE	COST/SHARE	ELIGIBILITY CRITERIA	MAX/OWNER
No-till	$15/acre	30%+ residue coverage	30 ac
Conservation tillage	$10/ac	30%+ residue coverage	30 ac
Field strips	$5/ac	0-2% slope, 660' strips 2-4% slope, 440' strips 4%+ slopes, 330' strips	90 ac
Canola planting	$5/ac	Sinkhole watershed	30 ac
Plow down seedings	$5/ac	Small grain cover to remain until April 15	30 ac
Winter cover crops	$10/ac	Following soybeans	30 ac
Soil type fertility testing	$6/test	CES recommended	$60
Pesticide management	$7/ac	2 lbs/ac or less a.i. pesticide usage	30 ac
Hay planting (sinkhole buffers)	$100/ac/yr (aft establistments)	Owner establishes and maintains 3 yrs, min 1 ac/sinkhole	5 ac
Grassed field borders/ field filters	$100/ac/yr (aft establishment	0-2% slopes, 10' strips, 2-4% slopes, 20' strips, 4%+ slopes, 30' strips. maintain for 3 yrs	5 ac
Filter strips	$100/ac/yr (aft establishment)	66' min. width along stream/ditch, maintain for 3 yrs	5 ac
Grassed waterway	50% cost	Severe gully erosion	$3000
Sediment control basin	75% cost	Trapping sediment/ nutrients in watershed of sinkhole	$3000
Sinkhole inlet structure	50% cost	Runoff control into existing sinkhole	$1500

Chapter 4. HYDROGEOLOGIC ACTIVITIES

4.1 Water level monitoring

One of the first objectives of this NPS project was to determine the direction of ground water flow. This would make it possible to measure the effectiveness of BMPs on ground water quality. To determine the direction of ground water flow, elevations of the water table were determined for the area of interest. To accomplish this, the depth to water at known surface elevations must be determined in as many wells as deemed necessary to accurately define the water table. By subtracting the depth to water from the surface elevation, a water table elevation can be determined for that well. Contouring of the individual data points results in a water table map.

In order to determine the seasonal variation of the water table surface in Thompson Township, 133 wells were measured in July, 1990, 69 wells in November, 1990 and March, 1991 and 98 wells in November, 1991. The water table was very high during March and April, 1993; therefore, a water level survey was conducted on 76 wells on April 22, 1993. Appendix A contains all the water level data collected during this project. From these data, water table maps of Thompson Township were constructed. The water table maps of July, 1990 (Figure 4) and November, 1990 during periods of low to normal precipitation, are relatively similar and exhibit two distinctive features.

The first water table feature in Thompson Township is the steep gradient that is observed southeast of Flat Rock. This corresponds to the contact between the Delaware and the Columbus Limestones. Since the Delaware Limestone is more dense and has much less secondary porosity than the Columbus Limestone, the water table is much more stable. As the water enters the Columbus Limestone, it encounters a less dense unit that has a high secondary porosity. The water levels in the Delaware Limestone, therefore, are much higher and the wells are set at lesser depths than observed in the Columbus Limestone. This steep gradient is therefore caused from the lithologic differences between the two units. The high secondary porosity of the Columbus Limestone causes the water levels to drop because the water moves at higher velocities.

The second striking feature on the water table map is the north-northeast trending low located approximately one mile west of Flat Rock. From Figure 4, it is apparent that water flows from both the east and west into this low and then flows towards the north-northeast. This anomaly was mapped by Kihn (1988) who suggested it was caused by a buried glacial valley, but research in this study alters this interpretation. The depth to bedrock in the central portion of the anomaly is less than 20 feet. Drane (1993) determined from geophysical surveys across the area

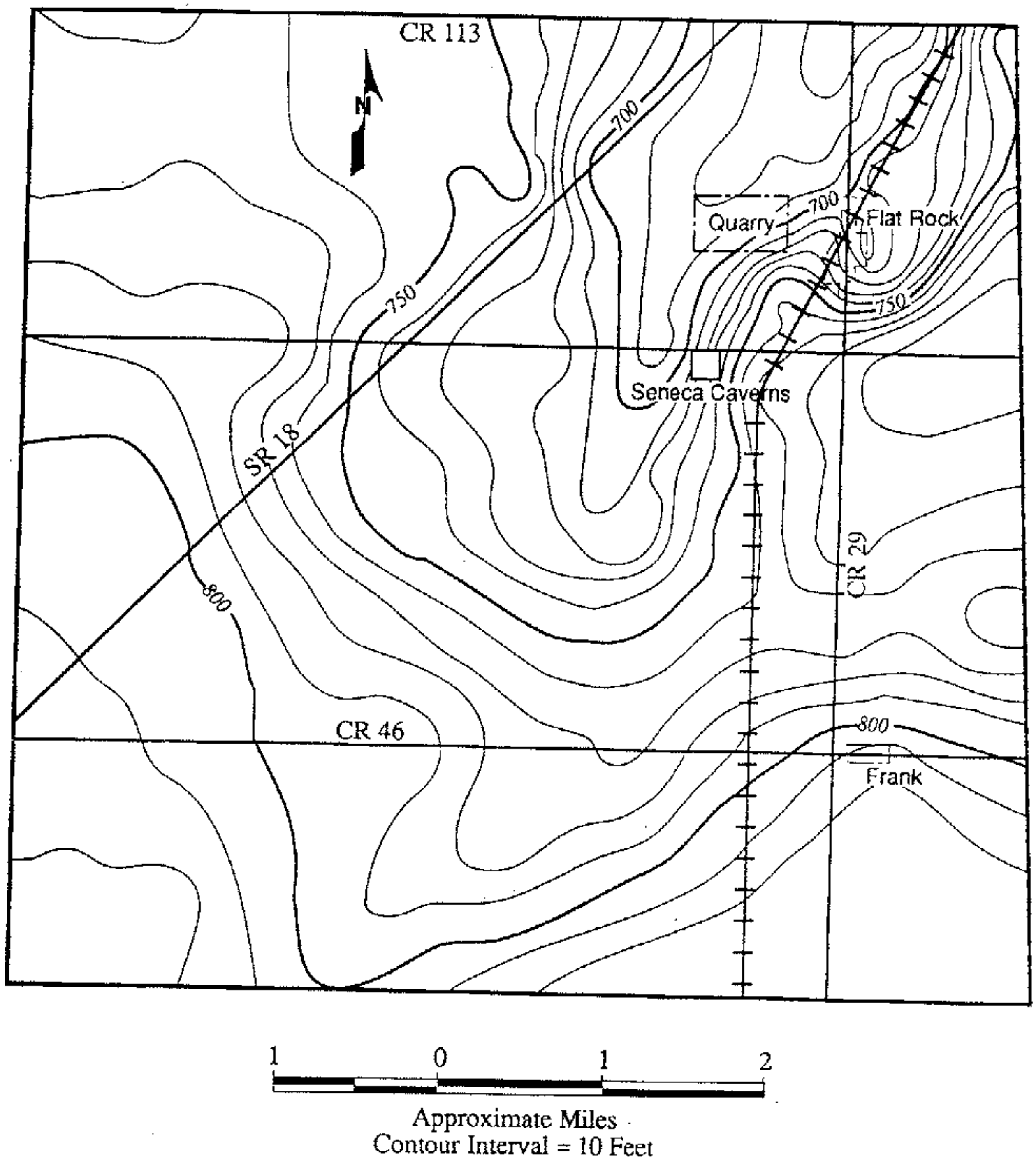


Figure 4. Water Table Map of Thompson Township
During a Period of Normal Precipitation, April, 1990.
(Modified from Drane, 1993)

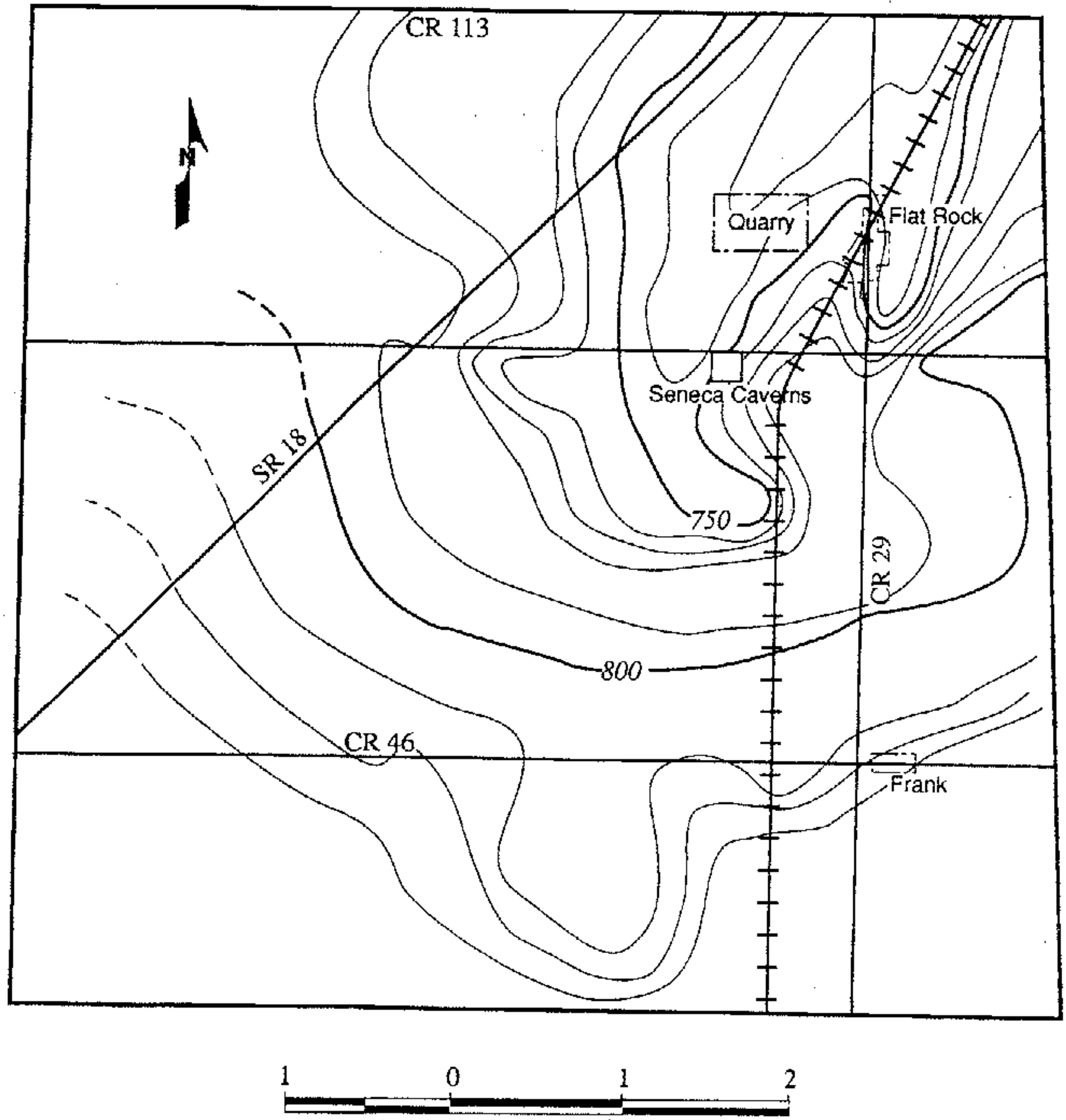
that a void exists within the limestone, which acts as a conduit to transport water in a northerly direction.
Heavy precipitation events in November, 1990, March, 1991 and April, 1993 caused water levels in the Township to rise significantly. In April, 1993, water had flooded the Flat Rock quarry to within thirty feet of land surface. Typically, the water level stays relatively constant in the quarry at a depth of approximately 100 feet below land surface. The quarry pumps only to wash the aggregate and usually does not have to pump to keep water levels below the working level in the quarry. The water level map for April, 1993 (Figure 5) shows that the direction of flow is not very different than during low ground water level times, however; the gradient is much less steep. Water levels in the northern section of the township were 40 to 60 feet higher than during the July, 1990 water level survey while being only 20 to 30 feet higher in the southern end of the township.

Apparently, precipitation was too great for the conduit system in the limestone to channel the water to the north. Because of this the ground water was not able to flow freely through the voids in the limestone as during low flow times.

To determine the rate of recharge to the limestone bedrock, one well within Thompson Township was monitored continuously. The well chosen is located in the western half of Section 23, along Township Road 82. At first, a graphical Stevens type recorder was installed at the well. The rapid fluctuations in the water table caused the float and counterweight to get off-balance and not work properly. To correct this problem, a pressure transducer was installed and programmed to take water level readings every hour. Figure 6 shows a typical hydrograph of the fluctuations of water levels with time. Increases in the water table are very steep after precipitation events, with a more gradual decline. This is what is observed in other areas where water movement is controlled by fracture or conduit flow. Observation wells maintained by the Division of Water in other parts of the state confirm this general trend.

During heavy storm events, the water level in this well was observed to be rising at over one foot per hour and has risen over 40 feet in less than a five day period (see Figure 7). Precipitation was correlated with water levels from different rain gage stations throughout Thompson Township during non-freezing months and from Heidelberg College during the winter months. Strong correlations can be seen in both Figures 6 and 7 between rainfall events and rising ground water levels.

Declines in water levels, as stated earlier, is not as rapid as the increases. Average rates of decline in the water table are on the order of one half to one and one half feet per day. This much slower rate of decline compared to the increase is due to the fact that the voids in the limestone can accept water very



Approximate Miles
Contour Interval = 10 Feet

Figure 5. Water Table Map of Thompson Township
During a Period of Above Normal Precipitation, April 1993.

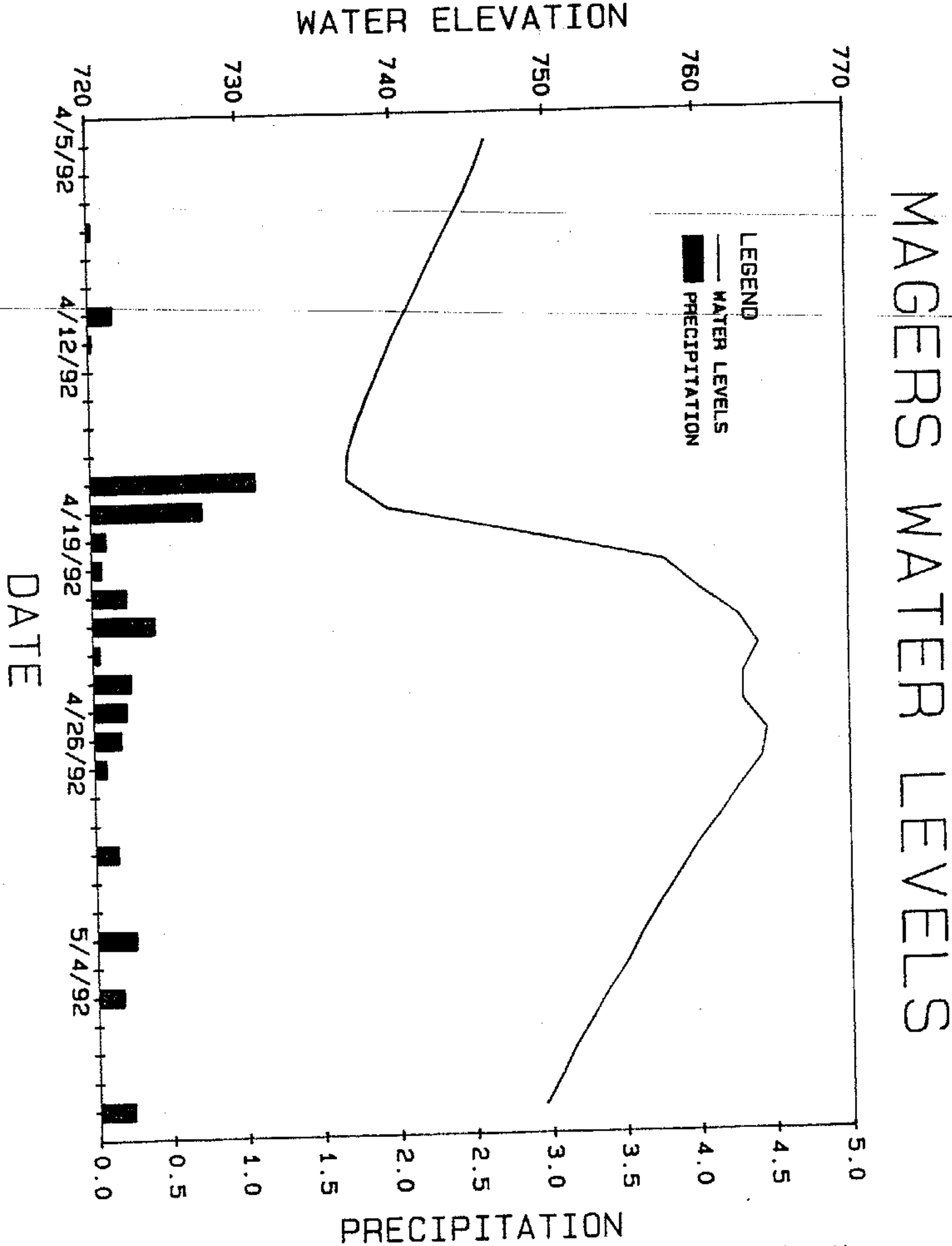


Figure 6. Hydrograph from Observation Well Located in Section 23 Thompson Township.

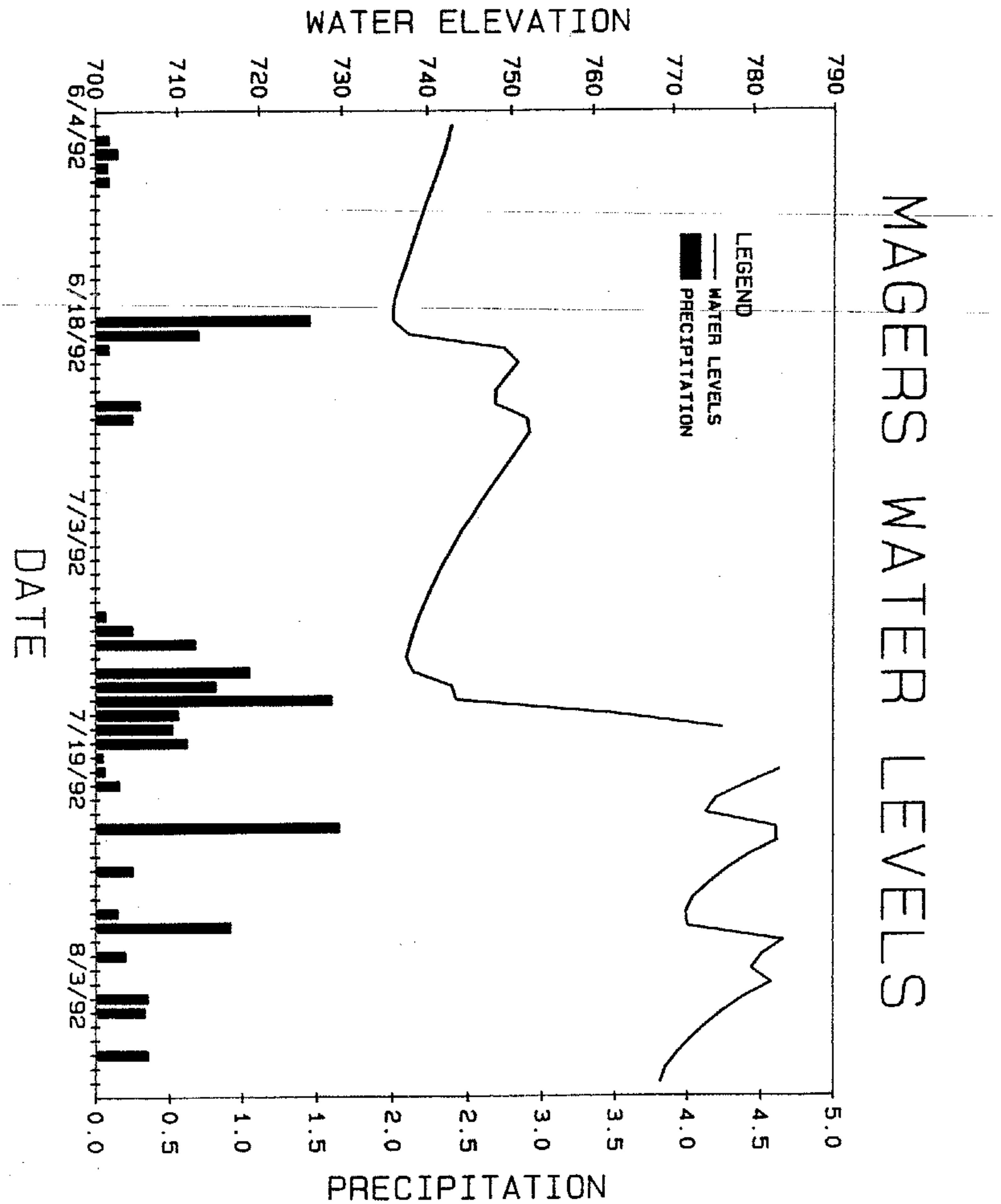


Figure 7. Hydrograph from Observation Well Located in Section 23 Thompson Township.
Period of Record: June 4 - August 10, 1992

rapidly. As the voids become filled with water, the hydraulic head within the aquifer will then control the flow of water down gradient. If the void openings become smaller to the north, or down gradient, the water flow within the limestone aquifer will be restricted.

4.2. Fracture trace analysis

As previously stated, the study area is located on the eastern flank of the Findlay Arch. As solidified rock is bent, fractures occur to alleviate the stress built up. If these fractures extend to the land surface, they will be represented by a linear feature. Fracture trace analysis is the mapping of the orientations of these linear features on the land surface.

When looking at aerial photographs of Thompson Township, it is very apparent that linear structural features, or lineaments exist. These linear features show up on the aerial photographs as topographic, vegetation, or soil tonal alignments that are not related to outcrop pattern or any man-made or induced feature (i.e. row crops, farming techniques, or transportation routes). Fracture traces may be revealed as straight stream segments, alignment of sinkholes or springs, or as vegetation differences. The fracture trace on the surface reveals the existence of a fracture, or possibly the existence of a cavern, or subsurface void at depth.

Lineaments were mapped for Thompson Township using low altitude aerial photographs, and a stereoscope for a three-dimensional view of the land surface. Lineaments were mapped only if there was no doubt that they were structurally controlled and not influenced by man. This means that these lineaments had to extend through at least two fields or continue in an area which indicated that the lineament was not man made. Roads, farm fences, railroad tracks, and channelized segments of Royer Ditch were not mapped. Also apparent on these aerial photographs was an abandoned railroad route that is not obvious on the ground. Historic records were used to determine that this linear feature was in fact the location of an old railroad route.

In the mapping of linear features the orientation of the lineament is also measured. In completing this fracture trace analysis, 120 linear features were mapped. Ground reconnaissance in the quarries and where the Royer Ditch flows on the limestone bedrock has verified the existence and orientation of these lineaments as fracture traces. The major orientation of these fracture traces is in a N45E direction, with a conjugate, or smaller set oriented N45W (see Figure 8). This is the main orientation direction of fractures throughout Ohio, and especially in northwestern Ohio.

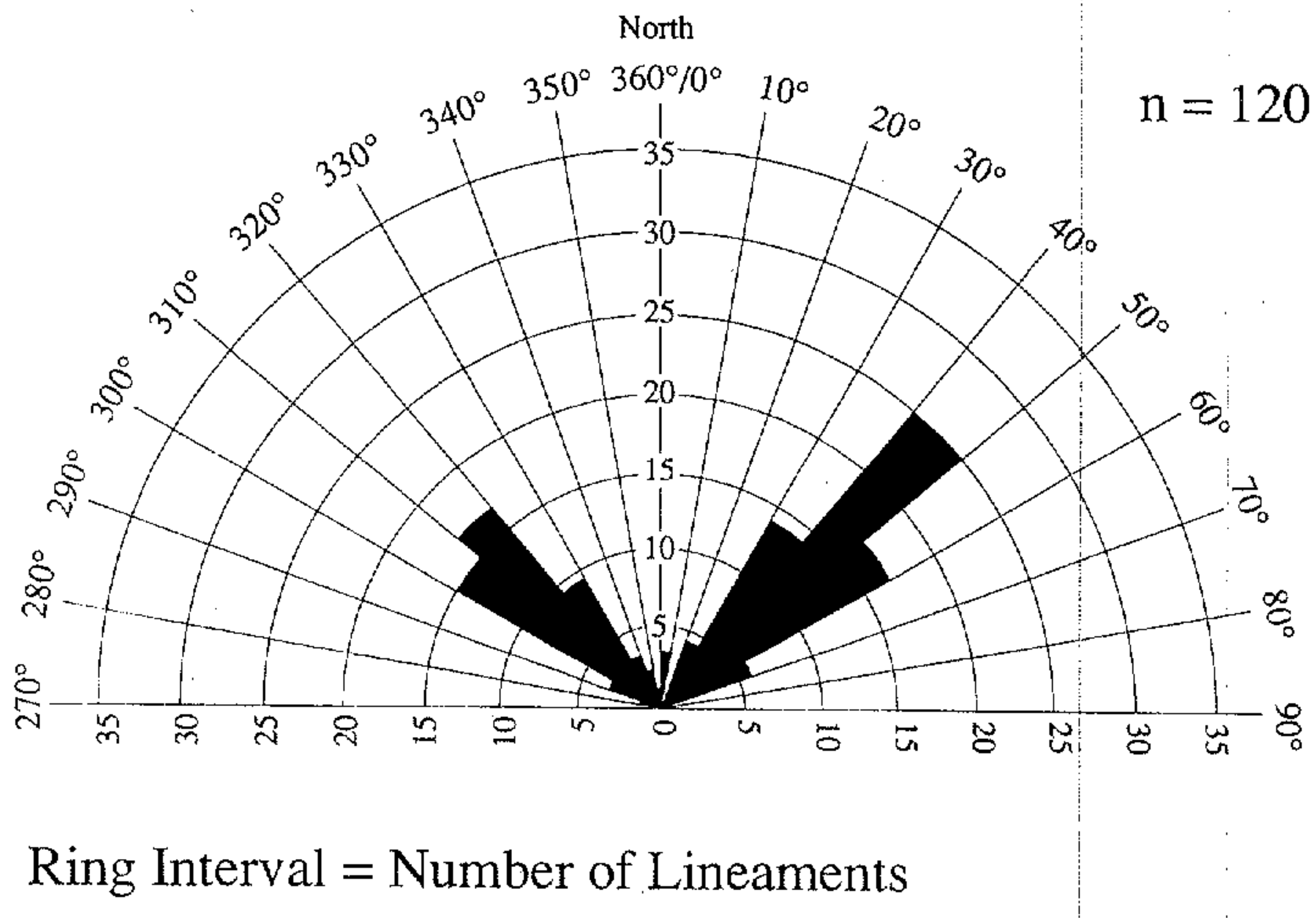


Figure 8. Rose Diagram of Lineaments Mapped From Aerial Photographs in Thompson Township, Seneca County, Ohio

4.3 Dye Trace Study

4.31 Methodology

Tracer techniques are frequently employed when studying a karst aquifer like the one present in Thompson Township. The use of dye can range from simply resolving the flow rate of a stream to studying the unique hydraulics of an aquifer. A dye trace study was incorporated into this project in order to better determine the flow direction and to approximate the flow rate of ground water in the study area.

Prior to beginning a dye trace, a collection of all geologic and hydrogeologic information was gathered and studied. This was done to better define and understand the possible results of a dye trace study. The path of the dye, and thus ground water flow direction was predicted before the dye was injected by constructing water table maps, by comparing the different lithologies of the limestones, and utilizing the topography of the area. The dye trace results should prove, according to the water table maps, that surface water, and accompanying contaminants that infiltrate into the subsurface in Thompson Township will travel in a north, north-east direction.

Several types of dye can be used to trace the flow of ground water. Among the most popular are the fluorescent Fluorescein and Rhodamine WT. Others tracers used are optical brighteners and direct yellow 96 (Jones, 1984). The dye used in the study was Fluorescein. Because of the unsuccessful dye trace study north of Bellevue in which 25 pounds of dye was used, fifty pounds was used in this study.

Prior to injecting the dye, background water samples were analyzed from 60 sites in order to determine the background fluorescence in the ground water. This background fluorescence can be a result of natural constituents in the ground water such as sulfur. This sampling was completed one week prior to the introduction of the dye. As the dye was being tracked, 24 more people were willing to participate in the project and were added to the original 60 that would be monitored.

Eighty-four sampling sites were chosen, most of which were located in an area north to northeast of the injection site. Several factors influenced the location of the sampling and recovery points. The first was the geology. The aquifer being studied is the Columbus Limestone which is considerably karstified where the overburden is 10 feet thick or less (Drane, 1993). The formation above the Columbus is the Delaware Limestone and below is the Lucas Formation, all of which trend northeast. In map view, the Columbus Limestone is bordered to the east by the Delaware Limestone and to the west by the Lucas Formation. These two bordering formations are carbonates but are not karst forming; therefore, it would seem likely that ground water flow would be controlled by the karst features within the confines of the Columbus Limestone.

The second factor was the results of the water level surveys which indicated the existence of a narrow water table low trending northeast from the center of the township. Water would flow towards this low and then to the northeast. These factors allowed for the monitoring sites to be picked more objectively rather than randomly.

Fifty pounds of Fluorescein was injected into the Big Sink on May 11, 1992 at 9:30 am. The Big Sink is an intermittent sinking stream located in the eastern half of Section 23 of Thompson Township. This Fluorescein dye was used because of its high detectability and low toxicity. The Big Sink was chosen as the dye injection point because of the direct inflow of surface water into the ground water system. The dye was diluted in 375-400 gallons of water and pumped into the sinkhole. The tank was rinsed three times, each at a capacity of 800 gallons. Natural flow of water into the Big Sink was approximately 20 gpm at the time of dye injection.

Activated charcoal was used to recover the dye and three methods of collection were used. Charcoal packets attached to fishing line were lowered into wells, packets were attached to "bugs" (a hanger and cement weight) to retrieve dye from open water, and screened hose adapters were used to recover dye from wells being pumped. One or more of the techniques were applied on property where permission was granted. The sites were sampled once a day for the first week and then biweekly to weekly for the next 15 weeks as the dye traveled to the north. The sampling frequency gradually decreased to once per month.

After each sampling, the charcoal was emptied out of its packet and placed into a plastic container. An ellutant was then prepared and poured onto the charcoal. The ellutant mixture for a twenty sample batch was 31.8 grams of potassium Hydroxide (KOH), 500 milliliters of Ethanol and 150 milliliters of water. The role of the ellutant mixture was to extract any dye from the charcoal. High concentrations of dye turned the ellutant green within three hours. With smaller amounts of dye, a fluorometer would be needed to detect the presence of dye. All samples collected were taken to Heidelberg College's Water Quality Lab for analysis.

4.32 Results of the Dye Trace Study

The dye trace began on May 11, 1992 and lasted approximately 1 year until the dye concentration was too diluted to make a positive confirmation as to the presence of the fluorescein dye.

The dye was first detected on May 28, 1992 at 4 monitoring sites located northwest of the injection site. Figure 9 shows the locations of all the sites monitored during the dye trace activity. The sites where dye was detected are numbered in order of the time in which detection was first noticed. From there, later detection sites were in a northeast direction. The dye was subsequently found at sites to the north and northeast for a distance of approximately eight miles from the injection site at the Big Sink.

From the dye trace study, the ground water travel time was calculated to be approximately 500 feet per day within the Thompson Township area. Distant sites where positive dye detections were made resulted in an approximate ground water flow rate of 400 feet per day.

4.4 Borehole investigations

Borehole geophysical and video techniques are used to obtain information about the geologic formations encountered during the drilling process. These techniques involve lowering the device into an existing well and measuring or observing the different properties of the formations. Changes in the lithology of the formations and the extent of fractures or voids can be measured using these techniques

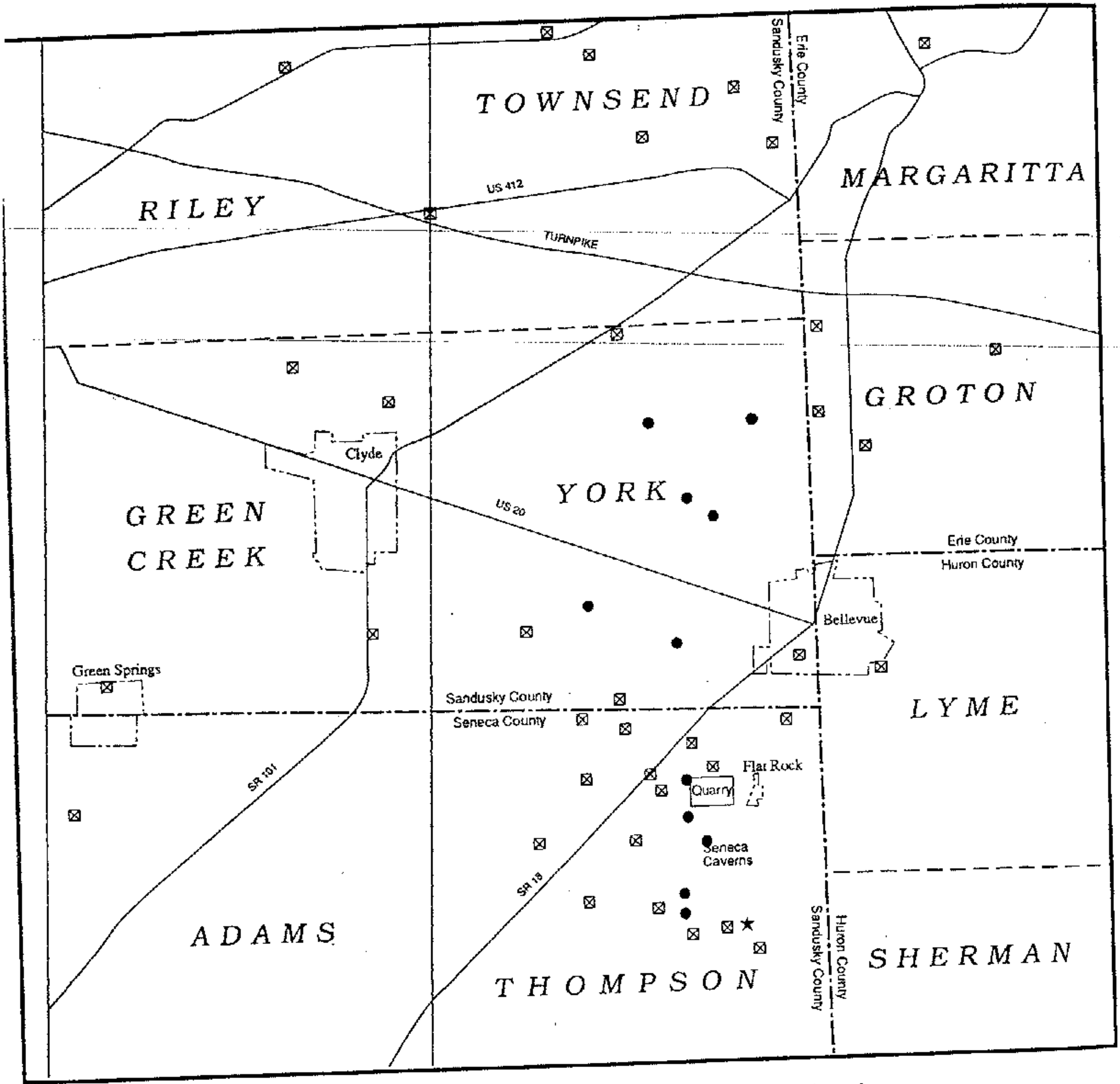
4.41 Caliper Log

On October 23, 1990 the GWRS conducted a caliper log survey of the Mager's well located along Township Road 82 in the northwest quarter of Section 23. A caliper tool consists of three adjustable legs that can sense the diameter of a borehole. This tool can be used to identify horizontal voids or fractures in the limestone bedrock.

After being calibrated, the caliper tool was lowered to a depth of 138 feet. The caliper was slowly raised and borehole diameter recorded in one foot increments. In order for the tool to register a larger borehole, the three legs had to extend outward. That is why this tool is very good at recording horizontal features in the limestone and not recording any vertical or subvertical fractures. According to the caliper survey, the diameter of the borehole did not vary by more than half an inch.

4.42 Gamma Log

Gamma ray logging is another type of borehole geophysical technique in which measurements are made of the naturally occurring radiation coming from the materials encountered within a borehole. Certain radioactive elements occur naturally in all types of rocks, including sedimentary rocks found within the study area. Clays and shales contain high concentrations of



1 0 1 2 3 4

Approximate Miles

Dye Trace Result

- ● Positive
- ⊠ Negative
- ★ Dye Injection Point

Figure 9. Location and Sampling Results of Dye Trace Detectors.

radioactive isotopes while limestone and dolomite typically emit low levels of radiation.

A gamma ray log of the Mager's well was conducted on October 23, 1990. The reason for the survey was to determine the heterogeneity of the limestone and to determine the depth to bedrock in this well. From the gamma log, the depth to bedrock was determined to be between 10 and 11 feet. One of the advantages of this tool is that it can be used in cased wells. The Mager well has 13 feet of casing.

Variations in the gamma ray log were slight throughout the entire thickness of the limestone bedrock. Very low readings (less than 10) were recorded from 138 to 84 feet. Between 84 and 11 feet, the gamma readings varied from 6 to 25. Readings from the clay rich till above the bedrock ranged from 35 to 47.

4.43 Downhole Camera

On December 20, 1990 a downhole camera well survey was conducted by the Ohio Department of Health on three wells with Thompson Township. The three wells surveyed were all long time inactive wells of which the water in two wells was too cloudy to obtain a clear picture. The Mager's well contained very clear water and a very good picture was recorded. Vertical fractures and enlarged bedding planes were seen throughout the video. Variations in color and bedding thickness were observed. The wide angle lens of the camera made some of the bedding plane features look very large but the caliper tool confirmed that solutioning of the limestone did not extend very far from the borehole.

Chapter 5. Water Quality Sampling Program

5.1 Sampling Methodology

Water quality problems in Thompson Township were first identified by a voluntary well testing program as previously stated. The Division of Water proceeded in conjunction with several other agencies to initiate the ground water quality phase of the hydrogeologic investigation for the study area. The first step of the study was to design a ground water sampling program for the Thompson Township area. A water quality sampling program was designed to cover a three year period. The original sampling plan was designed to include one "big set" per year and then a monthly "small set" of wells. The "big set" was originally 42 wells and the "small set" included 16 wells. Each sample was analyzed for eight parameters (Table 3) by the staff of the Water Quality Lab at Heidelberg College. Some of the samples were screened for the presence of Triazine and Alachlor. The Triazine screen measures atrizine and will detect symazine (Princep) and cynazine (Bladex) (Richards, 1992). The Alachlor screen measures alachlor and can detect metalochlor.

Table 3. Parameters tested for during the study with the detection limits and USEPA drinking standards.

Parameter	Detection Limit (mg/l)	Drinking Water Standard (mg/l)
Nitrate (as N)	0.1	10
Nitrite (NO_2)	0.01	2
Ammonia (NH_3)	0.1	35
Chloride	10	250
Sulfate (SO_4)	10	250
Conductivity	10 (Mhos)	1200
Total Phosphate	0.005	NA
Silica	0.1	NA

To make an accurate assessment of ground water versus surface water quality, it was necessary to sample surficial flow going into the sinkhole network. Grab samples were collected at the beginning of major storm events and then every other day for a five day period afterwards. A set of wells located down gradient from currently installed BMP's were also sampled. By comparing water quality of the grab samples with water quality in the down gradient wells a better understanding of the total flow system is possible.

In addition to this study, Heidelberg College Water Quality Lab sponsored a Time Variability Study on five wells within the study area. The purpose of this study was to get past the "snapshot approach" and look at changes in water chemistry that occur over time. The Time Variability Study may point out a underlying mechanism for some of the water quality problems experienced in the study area.

5.2 Initial Sampling

Historically high levels of nitrate and bacterial contamination have been an ongoing problem in Thompson Township. In December, 1988, the Seneca County Health Department enacted a building moratorium for the township. Local Health officials reasoned that the widespread well contamination was predominantly attributable to the use of faulty residential on-site sewage systems. They felt that any new systems installed would also fail and add to the problem that already exists.

The Health Department's position was further supported by the results of the voluntary well testing program of March, 1990. The average nitrate level in Thompson Township was 3.80 milligrams per liter (mg/l) in contrast to the county average of 1.67 mg/l. Thirteen percent of the wells tested in Thompson Township exceeded the safe drinking water standard of ten mg/l. Thirty-six percent of the wells tested exceeded the safe drinking water standard of four mg/l for bacteria. Traces of pesticides were present in two of the wells tested.

5.3 Annual Sampling

The annual sampling program was designed to analyze approximately 42 wells once a year. The first "big set" was run in March, 1991 (Appendix B). These yearly samples, which were distributed across the township (see Figure 10), would help define "hot spots" that could be looked at in more detail in the smaller monthly sets. Ground water was sampled for eight parameters (see Table 3), which varied greatly across the study area . Nitrate values ranged from .06 to 13.72 mg/l and averaged 3.96 mg/l. Even though this is below the drinking water standard, this high of average level is cause for concern because of the yearly variability in nitrate levels (Richards, personnel communication, 1991). Past results from Heidelberg's state well testing program has shown wells in the 3-6 mg/l range have a greater likelihood of exceeding 10 mg/l at some point in the year.

Except for Sulfates, all of the remaining parameters averaged below any drinking water standards: Ammonia, 0.002 mg/l; nitrites, 0.002 mg/l; chlorides, 20.96 mg/l; sulfates, 341.45 mg/l; conductivity, 1078 mhos; phosphorus, 0.0053 mg/l; and silica, 9.14 mg/l.

In March, 1992 the annual sampling was performed again. This time 38 wells were sampled. The only major variability between the two years was in nitrate levels. The 1992 set averaged 1.54 mg/l with a high reading of only 8.26 mg/l. The nitrate levels were much lower because of the reduced levels of precipitation across the study area. The study area experienced a severe to extreme drought. The lack of rainfall left no mechanism to "drive" nitrates from the soil into the ground water system. The nitrogen present was mostly uptaken by vegetation.

In April, 1993 the last annual sample was collected. Thirty-seven wells were sampled in this set. Again the major

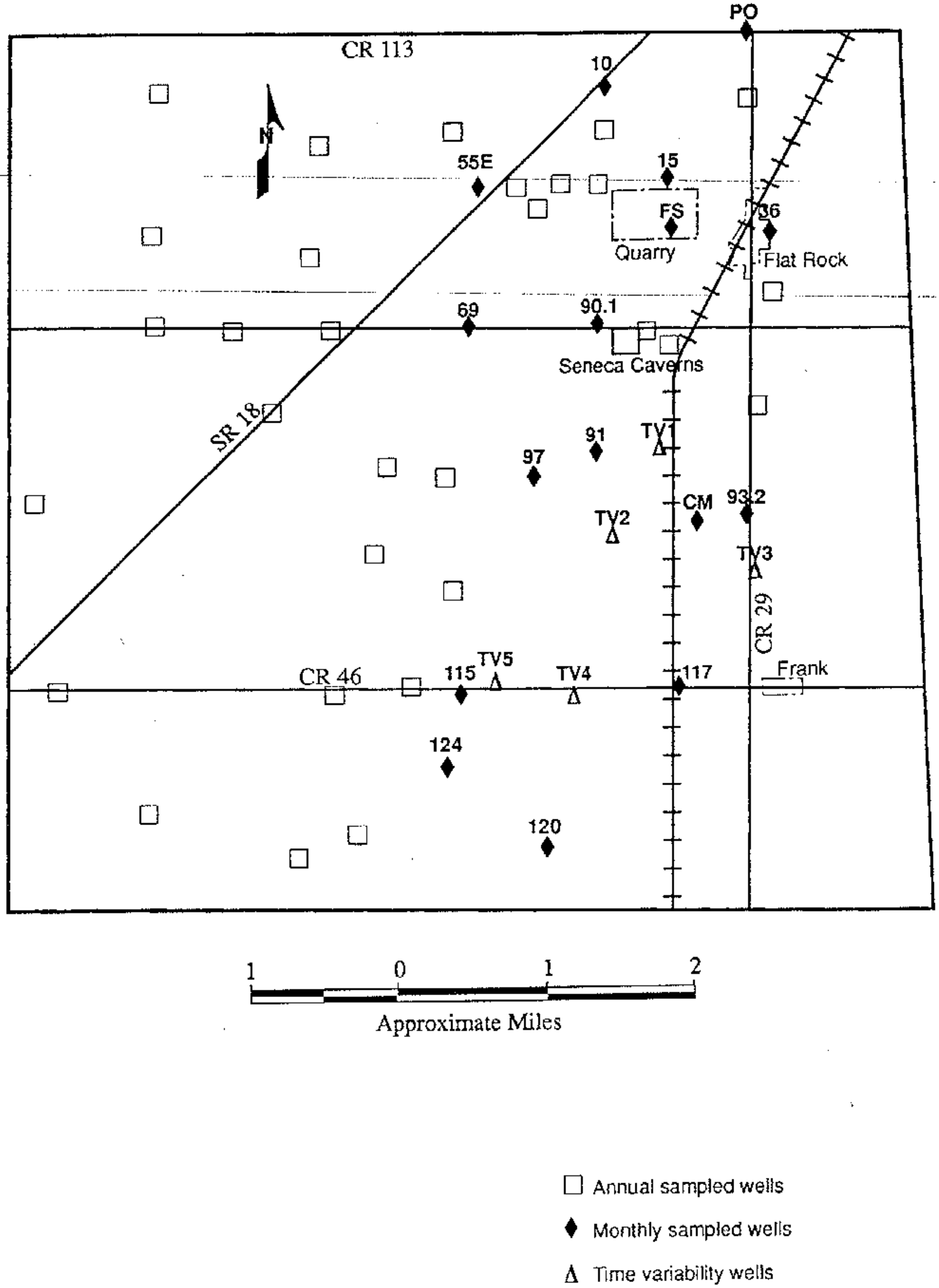


Figure 10. Location of Water Quality Sampling Sites.

variability occurred in nitrate concentrations. Nitrate levels varied from a low of 0 mg/l to a high of 15.27 mg/l. Eleven percent of the wells exceeded the safe drinking water standard of 10 mg/l. There were no significant changes in the rest of the parameters sampled.

A point that deserves noting is the relationship between nitrate and sulfate levels. In wells where nitrate levels are elevated, sulfate concentrations are low. In wells where sulfate levels are high, nitrate levels are low. This phenomena is clearly attributable to surface water versus deeper ground water flow. High nitrate waters are composed of predominantly surface water that has been directly recharged to the aquifer through the sinkhole network. High sulfate waters are from the deeper regional flow system of the carbonate bedrock. There is a very complicated interaction between the direct "autogenic" recharge water and water from the deeper flow system of the carbonate rocks. Because of the limitations of the sampling procedure the composition of the intermediate waters is not clear.

5.4 Monthly Sampling

A set of wells in the eastern section of the township were selected for monthly sampling (see Figure 10). These wells were sampled from March, 1991 to July, 1993. The set included one hand dug well and 15 water wells finished at various depths. Chemical analysis results between individual wells have shown no obvious correlation. The high degree of heterogeneity of the karst aquifer system adds to the mixing of water chemistries. Movement of water in this system is controlled by the flow through fractures, subsurface voids, caverns and solution openings. These may or may not be hydraulically connected. This system is very dynamic as verified by the extreme and rapid changes in static water levels. The connection of these flow paths causes the waters to mix, thus creating different chemical properties.

Nitrate concentrations varied throughout the sampling period. Nitrates ranged from 0 mg/l to 11.98 mg/l with an average of 2.14 mg/l. Nitrates enter the ground water system in a variety of ways. Manure, sewage and various types of ammonia fertilizers generate ammonia. Bacteria in the soil horizon convert ammonia into nitrate through the process of nitrification. In an area where direct aquifer recharge is common, the application of nitrogen fertilizer is especially problematic.

Precipitation is the mechanism for driving surficial nitrogen into the ground water supply. The abundance of sinkholes in Thompson Township permits surficial contamination to be recharged directly into the ground water system.

Nitrites are rarely found naturally in high concentrations in ground water. They are usually found where bacteria is breaking down into ammonia and nitrates. The low levels of nitrites observed is because nitrites are quickly oxidized into nitrates. Nitrite levels ranged from 0 mg/l to 1.098 mg/l. The presence of higher nitrite levels is reflective of the pollution problem that exists in the study area.

Ammonia concentrations in Thompson Township range from 0 mg/l to 0.891 mg/l. Most of the higher readings came from one well, which would indicate a point source type of contamination. The safe drinking water standard is 35 mg/l. The presence of any amount of ammonia indicates that animal waste, sewage, fertilizers, or sewage effluent are reaching the aquifer system.

The chloride concentration is also indicative of waste product in the water supply. Levels of chlorides varied from 5.80 mg/l to 146.20 mg/l. This is well below the safe drinking water standard of 250 mg/l. Certain wells in the study contained high chloride concentration, while the yearly average was less than 15 mg/l.

Sulfate levels in the monthly sampling for many wells exceeded the safe drinking water standard of 250 mg/l. Sulfate levels varied from 5.70 mg/l to 1760 mg/l. Because of the type of autosampler used by the water quality lab, some of the higher levels of sulfate went overscale. Wells exhibiting high sulfate levels are assumed to be from the deeper water source in the carbonate aquifer. The high sulfate concentrations are from the gypsum, that is present in the Devonian-aged Bass Island Group bedrock, going into solution. Elevated sulfate concentrations are common in the Silurian and Devonian Carbonates of Northwestern Ohio. Digestive tract problems are common from people unaccustomed to drinking high sulfate waters. Many individuals adapt and drink this type of water with no ill effects.

The presence of salts or other types of impurities cause an increase in the ability of the water to conduct electric current (conductivity). Conductivity is a way to determine the amount of impurities present in a water supply. Conductivity values ranged from a low of 0.23 mg/l to a high value of 3935 mg/l. Most values were between 700 and 1700 mg/l.

Silica was another constituent sampled during the study. Silica can produce scale that coats the inside of wells, pipes and boilers. Most of the silica present is from the glacial drift that leaches into the ground water supply. Kihn (1988) found chert nodules present in the Columbus Limestone, which could account for the high concentrations found.

Total suspended phosphate found in water is most likely derived from the small amounts of phosphate minerals in the carbonate units and from fertilizers containing phosphate. Phosphate levels were low in all samples tested.

Pesticide screens were run on the 16 wells during the months of April, May, and June 1991; April 1992; and July, 1993 (Appendix B). Most pesticides in this area are applied in late April to early June. The drought of 1991 inhibited the movement of pesticide leading to attenuation of the pesticide applied to fields in the area. Alachlor and Triazine were the pesticides screened for in the study. Pesticide concentrations in Thompson Township varied from 0 ug/l to 13.5 ug/l for triazine and 0 ug/l to 1.84 ug/l for atrizine. One well (well CM in Figure 10) was screened for alachlor and triazine seven times in 1991. Triazine levels exceeded the safe drinking water standard of 1.0 ug/l, five times. The other two months, levels were just below the standard. Alachlor was only found to violate the safe drinking water standard once during the seven months.

5.5 Storm Event Sampling

An important component of the sampling program was the storm event sampling (grab sampling). To understand the changes that occur in ground water chemistry, it was necessary to get samples of the surface waters that directly recharge the aquifer system. Since few of the sinkholes have continuous flow, it was necessary to "grab" a sample of the runoff water during major storm events. The samples from storm events would also have the highest concentrations of any agrichemicals that have runoff adjacent agricultural lands. Comparisons can then be made with ground water samples that have been collected down-gradient of a sinkhole to determine what amount of a nitrate or pesticide has made it into the ground water system from surface runoff.

Four sinkholes were selected for storm sampling (Figure 11). Three samples were collected from the three smallest sinkholes and four samples from the "Big Sink" during the first storm event on April 15, 1991. Four samples were collected on June 2, 1991, two from the "Dick Sink" and two from the "Big Sink." The other two sinkholes had insufficient flow to sample from. The samples were analyzed for the same components as the "large set" samples (see Appendix B).

The three samples collected during the first storm event from the Dead Dog Sink yielded nitrate levels of 28.28, 19.37, and 92.01 mg/l. These high nitrate levels were found because nitrogen had been applied to the adjacent field two days before the storm. The nitrate levels from the sinkhole on the Conservation Reserve Lands were 0.48, 0.51 and 0.38 mg/l. Runoff samples from the "Dick Sink" were found to have nitrate concentrations of 9.41, 9.21 and 10.64 mg/l. During the second storm event levels were slightly higher at 12.03 and 12.23 mg/l respectively.

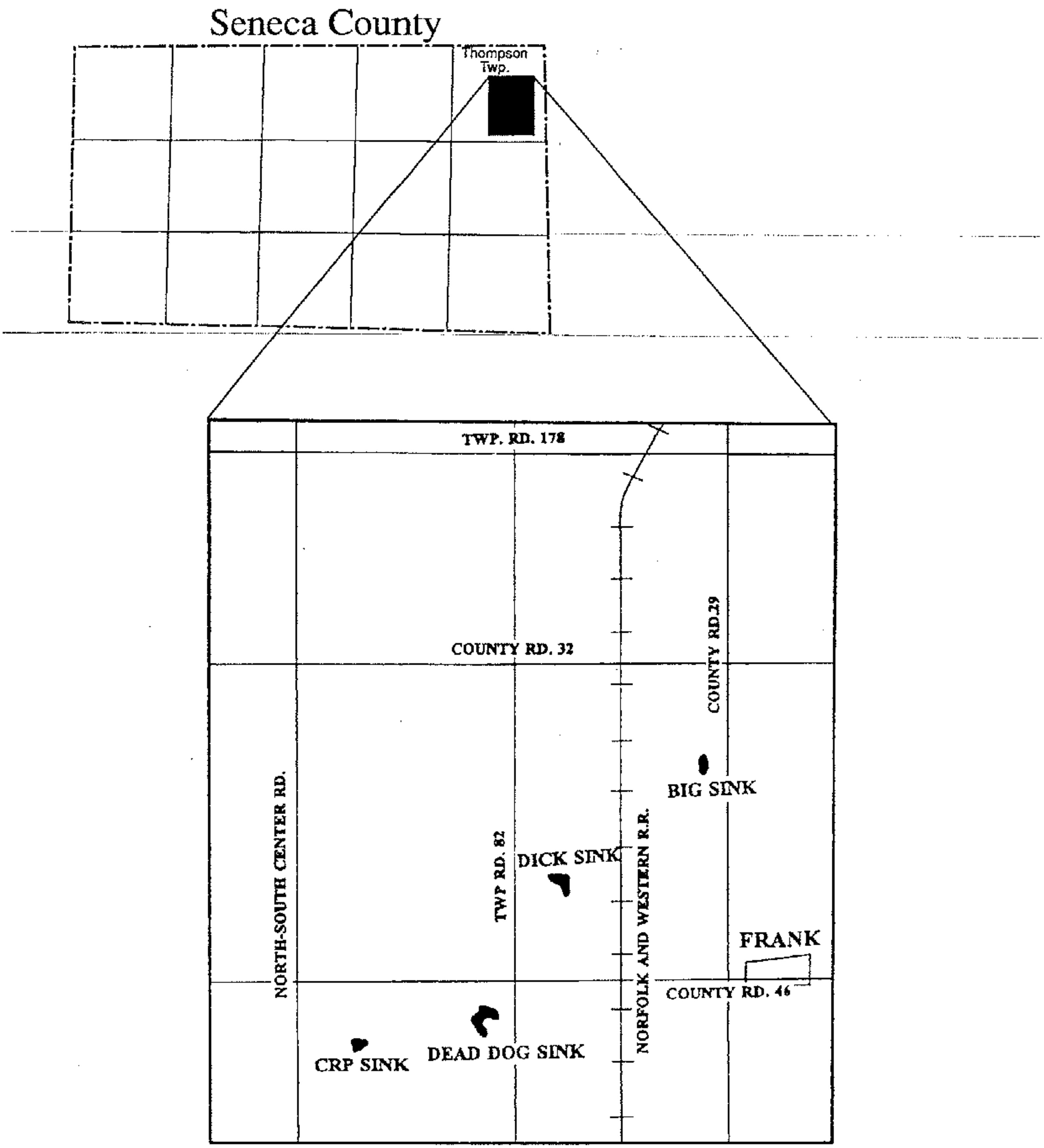


Figure 11. Location of Sinkholes used to Collect Grab Samples.
Modified from Drane, 1993.

The "Big Sink" recorded concentrations of 1.95, 2.00, and 1.64 mg/l for the first storm event. During the second storm event nitrates were higher at 3.46 and 36.72 mg/l. The "Big Sink has such a large drainage area that it is difficult to determine if these numbers are accurate. Research in Iowa has shown that nitrate peak concentrations are found after the storm discharge peak (Libra et al., 1992). No discharge measurements have been taken on Snyders Creek and therefore the sampling period may not have been after the storms peak.

All of the samples collected from the sinkholes exhibited ammonia ~~and nitrite values much greater than were observed from the~~ samples collected from down-gradient water wells. The most probable explanation is that ammonia and nitrite are quickly reduced to nitrate through nitrification. Although no pesticide screens were run on the grab samples, one of the down gradient wells showed a major hit for Triazine after the storm event.

Four wells down-gradient from the four sinkholes were sampled after the second storm event. Three of the wells were sampled the day after the storm, three days later, and five days later. The fourth well was only sampled two times. The Miller well, located down-gradient from the "Big Sink", showed nitrate values of 10.89 and 3.24 mg/l. The first sample contained 13.5 ug/l of triazine and 0.90 ug/l of alachlor. The second sample contained 1.65 ug/l of triazine and 0.33 ug/l of alachlor. The Miller well lies along the trend of a major fracture that intercepts the "Big Sink". All the other wells sampled showed elevated levels of alachlor, although none of the levels approached the safe drinking water standard.

The work plan originally called for more surface water grab samples. However; the location of the sinkholes, and the duration and intensity of precipitation events did not make it feasible. (see Chapter 9 on Pitfalls/Problems Encountered)

5.6 Time Variability Study

Heidelberg College Water Quality Lab initiated a sister study designed to look at the time variability aspect of the study area. The study was designed to show how water quality contamination varied over time. The Time Variability Study is part of a larger study of the concentrations of agrichemicals in residential well supplies (Baker, 1992). A set of five wells were sampled weekly in the study area for the eight parameters and the two pesticide screens (See Figure 10). Appendix B contains water quality results for these wells. Only one well showed any pesticide contamination, and that well is located on the major fracture set that has been identified with the "Big Sink".

Chapter 6. Installation Of Best Management Practices

6.1 Objective and Goals of Best Management Practices

The major goal of a BMP in karst terrain is to reduce the flow velocity of storm water within the watershed of a sinkhole. This in combination with proper nutrient management, will reduce the amount of pollutants entering the sinkhole and thus the ground water system.

Properly installed and maintained soil coverings (buffer strips) will reduce the erosive effect of a raindrop as it falls. This same soil covering will also reduce the velocity as storm water moves toward the sinkhole. The wide variety of coverings range from grass/legume buffer strips around the sinkhole structure, to grassed waterways in concentrated water flow areas of a field. The field may also be separated into three or four sections of different crops(i.e. corn, soybeans, wheat, hay). This will disperse the surface water flow direction, which reduces the velocity of the water thus decreasing the erosion of soil particles suspended in water. Figure 12 demonstrates the many practices that are being used in karst terrain, such as Thompson Township. Not all of the practices are or must be used in the same field; however, they can all be used in conjunction with one another.

The major drainage of surface water in Thompson Township is via sinkholes; therefore, these sinkholes must remain open and drain properly. Flooding, resulting in road closings and crop damage is very common in this area. Sinkhole structures are thus needed in conjunction with buffer strips to stabilize the soil around the sinkhole while reducing sediment loadings to the ground water system via the sinkhole. These practices should reduce erosion, decrease the velocity of water entering the sinkholes, and help to absorb sediment, nutrients and pesticides. Winter cover crops are being used to reduce erosion as well.

6.2 Best Management Practices Installed

Tables 4 and 5 are lists of the BMPs installed with their corresponding size or number, amount of soil saved per acre per year, and the total soil saved per year from eroding into the sinkholes. Figure 13 shows the locations and types of BMPs installed within the Thompson Township during this project.

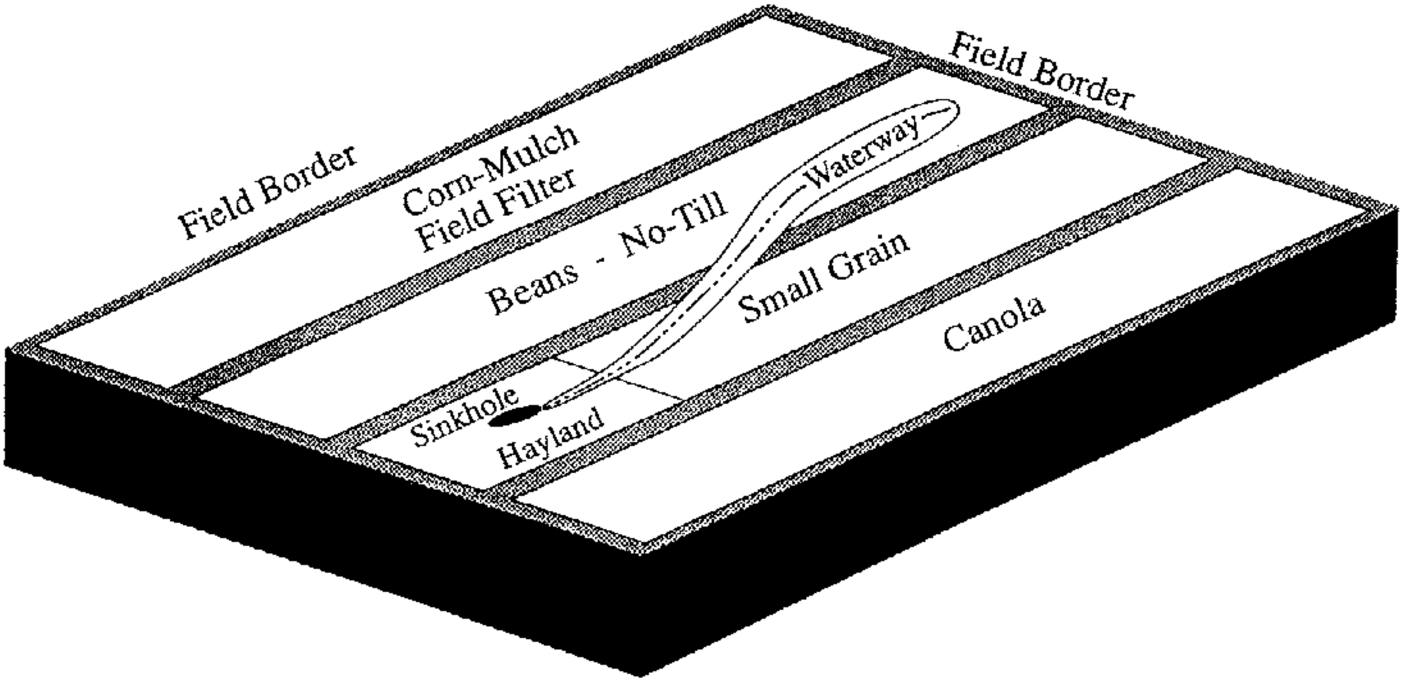


Figure 12. Example of Best Management Practices Utilized in Karst Terrain (2-4% grade)

Table 4. Best Management Practices and Acres Cost Shared With the Estimated Total Soil Erosion Savings Per Year Using the Universal Soil Loss Equation

Practice	**Size (in acres)**	**Soil Saved Tons/acre/year**	**Total Tons saved per year**
Sinkhole buffers	26.5	2	53.0
Filter Strips	6.7	2	13.4
Cover Crops	25.0	1	25.0
Field Strips	31.9	2	63.8
Field Filters	1.1	2	2.2
CRP Ground	1,084.4	5	5,422.0
Cons. Tillage	78.0	3	234.0
TOTAL	**1,253.6**		**5813.4**

These soil savings figures listed in Table 4 were estimated using the Universal Soil Loss Equation (USLE) :

$$A = RKLsCP$$

where:
- A = Ton/acre/year soil loss
- R = rainfall factor
- K = Soil Erodability factor (depends on soil type)
- Ls = Length and Slope factor
- C = Cropping Factor
- P = Erosion control practice factor

An example for soil savings for conservation tillage can be found in Appendix E.

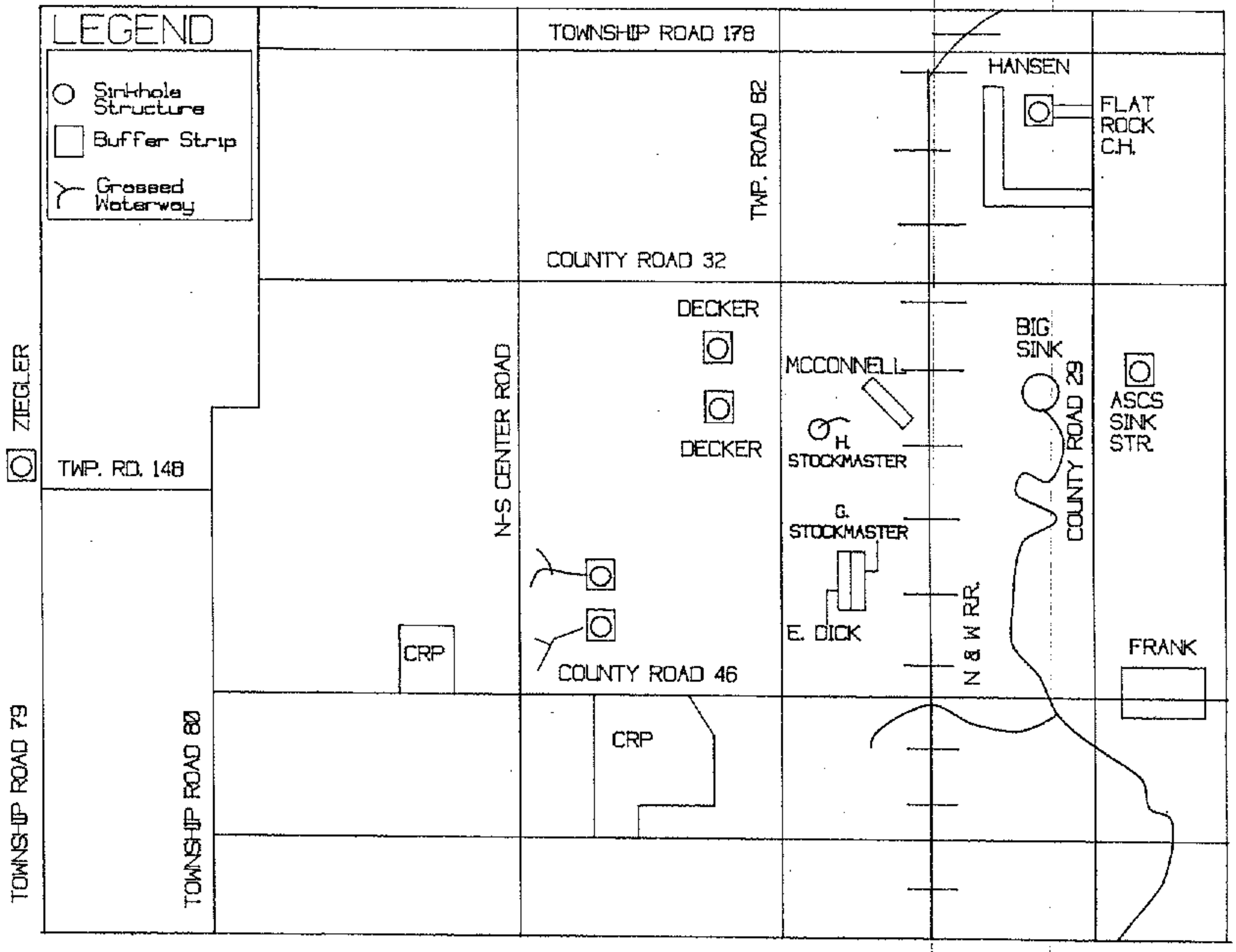


Figure 13. Location of Best Management Practices That Were Installed During the NPS Project.

Table 5. Best Management Practices with Estimated Soil Saved Per Year using the Gully Erosion Equation.

Practice	Size (in length or number)	Soil saved/unit	Total Tons saved per year
Grassed Waterway	2100 ft.	0.1	210
Sinkhole Structure	6	23.5	141
Total			**351**

For the practices listed in Table 5, the gully erosion formula was used to estimate soil savings. The numbers used in the table are averages for waterways and sinkhole structures that were installed. Appendix E contains examples of the gully erosion equation as it pertains to these structures.

As a result of implementing the BMPs listed above within the study area, approximately 508.4 tons of sediment will be prevented from eroding from the fields and entering the sinkhole areas each year, not including CRP ground and Conservation tillage (see Tables 4 and 5).

Along with the sediment, a similar portion of soluble contaminants such as nitrates, herbicides and pesticides are reduced from entering the ground water system via the sinkholes through the development and implementation of Water Quality Special Project Conservation plans. These plans have been written for 8 farms within Thompson Township. These plans encompass approximately 94 acres and will significantly help in reducing the soluble contaminants from entering the ground water system.

Approximately 1085 acres are registered in the CRP program and 78 acres are in conservation tillage within the study area. This amounts to another 5734 tons of sediment being kept on the fields annually that might have run off otherwise.

However effective these BMPs are, none of these practices will reduce concentrations of all pollutants. Nutrient management must be a vital component of these practices. Nutrient management is very crucial in connection with other BMP practices to reduce ground water pollutants.

This procedure starts with soil testing of all fields in the sinkhole watershed area. These tests are taken in each field by soil type. Different soil types will absorb, hold, and disperse nutrients differently. Clay soils have a higher cation exchange capacity which allows the soil to hold more nutrients than a sandy soil. Sandy soils have a tendency to release more nutrients at one time, whereas clay soils release smaller quantities of nutrients over a longer period of time. Timely fertilizer applications by soil type is crucial.

Crop yields also vary by soil type. It is important to consider the average yield ability of the soil type. If a field has a historical average yield of 110 bushels of corn per acre, it is better to apply only the amount of fertilizer needed to match this yield amount adjusted for growth and reasonable gains through different management practices. The impact of such a program, although in the best economic and environmental interest to the farmer, is slow to form as each producer plans for high yields that can only be realized given all conditions are perfect (i.e. weather, germination rate, depth of planting, harvest conditions, weed control, etc.). Landowners should consider using only the fertilizer needed by historical yield averages, and apply the fertilizer based on soil type information. The landowner can then achieve a realistic yield, reduce fertilizer costs, and improve water quality, all at the same time.

6.3 BMP Cost Share Expenditures

The total cost share of all BMPs in Thompson Township (Not including CRP or Conservation Tillage) was $17,976.34. The life of these practices is an average of 10 years. The total soil savings for the ten years would be 5084 tons. The average cost per ton of soil saved is $3.54. This cost per ton is very economical considering the average cost per ton of soil saved on Conservation Reserve Program ground is $17.00.

Soil sampling can be of even more value considering the cost to analyze the soil for nitrates. A portable nitrate meter can be used to determine the nitrate concentration for less than $1.00 per sample. This could result in a significant savings in fertilizer costs and possible ground water treatment costs in the future.

Chapter 7. WASTE WATER MANAGEMENT COMMITTEE

7.1 Objective and goal of Wastewater Management Committee

As already stated, high levels of nitrates and bacteria have been found in the township's drinking water. The establishment of a building moratorium in 1988 for Thompson Township halted building operations and began an awareness of the need for water quality improvements. The building moratorium was lifted in 1993; however, new development is limited to a site by site basis until such a time as pollution is controlled. In order to lift the regulation, a Waste Water Management Committee was developed to manage septic systems and improve the water quality in Thompson Township, which is necessary for both public health and protecting the environment.

The objective of the Waste Water Management Committee is to establish better water quality in Thompson Township. The research data that is being collected will be used one day to permit new building and development in the township. The gains from this effort are better water quality, as well as an increase in the economic base of the Thompson Township area.

The goals of the Committee are to establish water testing programs that can be used in monitoring progress, developing alternative septic and waste systems, and working with the Thompson Township Task Force and the Seneca County Soil and Water Conservation District to provide BMPs for non-agricultural landowners.

Activities carried out by the Management Committee have been a septic system survey of over 50 percent (238 residents) of the Thompson Township residents, a septic system inspection and pumping cost share program, and a water conservation kit sale. Appendix C contains a copy of the septic system survey and results, a copy of the septic system rebate form, and a list of the items contained within the water conservation kit. During this project, 25 septic systems were inspected and cleaned.

The Waste Water Management Committee is continuing to meet on a monthly basis even though NPS funding for this part of the project is over. This shows that there is strong local support and initiative to improve ground water quality.

7.2 Optical Brightener Study

As discussed previously, one of the chemical parameters being sampled for in this NPS study is nitrates. There are several potential sources for nitrate contamination in these wells: nitrate fertilizers, animal waste, human waste, decomposing plant debris, and industrial waste chemicals (Driscoll, 1986). In order to determine the most likely source for nitrate contamination, an attempt was made to identify some of the sources. Identification of domestic septic systems as a source is made possible by testing wells for optical brightener.

Optical brighteners are fluorescent dyes found in most laundry detergents. In most homes utilizing septic systems, the laundry water is discharged into the septic system along with the rest of the waste water from the home. Optical brighteners are not degraded by septic systems. However; if a septic system and leach field are working properly, the optical brighteners should not leave the system. In some older homes, laundry drainage may directly discharge onto the ground or in a nearby ditch and bypass the septic system completely. The proximity of the laundry discharge, if not hooked to the septic system, must be determined for any well in which optical brighteners are detected. If a particular well is being contaminated by a septic system, then optical brighteners should be present in the well water (Aley, 1985). The suspect septic system would then be located in an up-gradient ground water flow direction.

The test for optical brighteners is relatively simple. A screened packet containing cotton balls that were not treated with optical brightener were inserted into the toilet holding tank. This packet was left in the tank for a period of seven to ten days. The holding tank was chosen because of the possibility of a great amount of water flow through the packet. The packets were removed and the cotton balls rinsed with distilled water. When held under an ultraviolet light, any optical brighteners present on the cotton balls will fluoresce as a bright white color.

Homeowners that had high bacteria and nitrate results in the 1990 countywide study were targeted for the optical brightener study. Only 10 homeowners agreed to have the test conducted. Of the ten samples, three samples showed positive for optical brighteners. Figure 14 shows the locations of the optical brightener study sites. Positive samples were collected at sites 5, 6, and 8.

The results of this test would seem to indicate that for seven of the ten sites, the source of bacteria and nitrates is not from faulty septic systems. In an area with shallow karst geology (over 250 sinkholes within Thompson Township) there are many avenues for surface water to enter the ground water system. For this area, the amount of surface water recharging the ground water far exceeds the amount of septic discharge.

Of the three samples that came back showing the presence of optical brighteners, septic system influence is likely the problem. Septic systems up-gradient of these wells should be examined to determine the effectiveness of these systems and to make any needed improvements. In areas of shallow bedrock, some systems are installed on or in the limestone bedrock.

There are several methods to eliminate the problem caused by unwanted substances leaving the septic system and entering the ground water system. Routine cleaning and maintenance of the septic system may alleviate the problem. The septic system may need to be replaced, relocated or have a different type of sewage

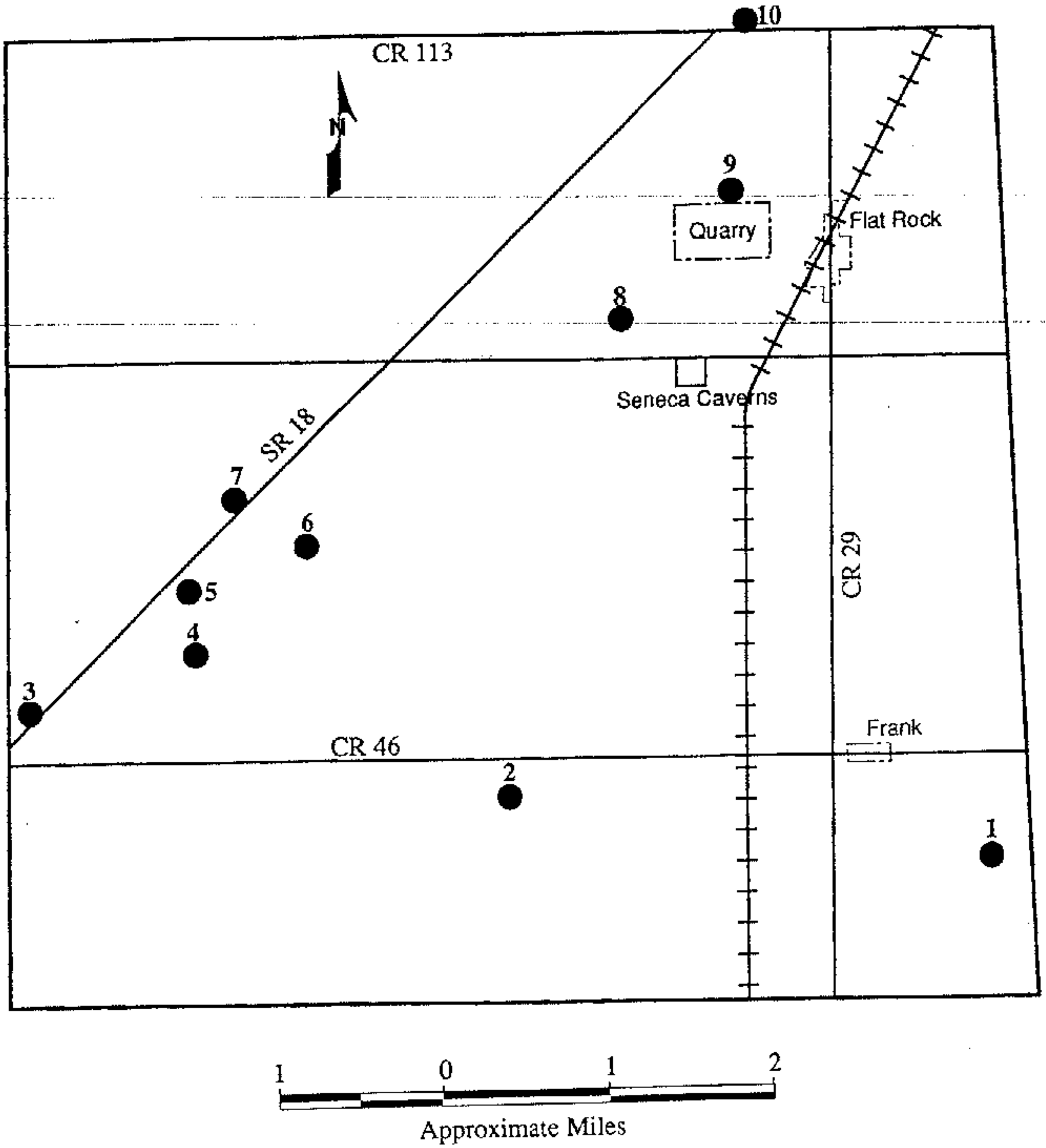


Figure 14. Location of Optical Brightener Study Participant Wells.

disposal installed. Conventional septic systems and leach fields are not suited for areas with limited amounts of unconsolidated sediment above the bedrock. This conventional type of septic system has been installed on or in the limestone bedrock within the study area. Other alternative methods are being examined by the County Health Department and the Wastewater Management Committee.

Chapter 8. Education And Public Meetings

Education and public participation were key components of this project. Without local participation, one could not expect to observe an improvement in ground water quality. A Task Force Group was assembled which consisted of federal, state, and local employees, as well as landowners and interested parties. The task force met on a quarterly basis starting in August, 1990.

As part of this project, a Waste Water Management Committee was formed in December, 1991. This committee is made up of a cooperative between urban landowners in Thompson Township and local agency personnel. Monthly meetings were held in which different waste water issues and projects were discussed. This group is dedicated to improving the ground water quality in this area by pursuing other avenues for grants and low interest loans to improve the efficiency of septic systems in Thompson Township. Work by this committee was helpful in the Seneca County Health Department removing the building moratorium in Thompson Township.

The following is a listing and description of all of the public meetings and tours held in the study area:

- July, 1990, To initiate the project, a public meeting was held at the Thompson School. The entire scope of the project was discussed to an audience of approximately 100 people.

- November, 1990. Dr. Karen Mancl, OSU Extension Office, taught a wastewater management workshop to 24 individuals. The five session workshop explained how different wastewater systems could be used in certain situations, and what questions need to be considered in the determination of what system to install.

- June, 1991. Thompson Township Public Sinkhole Tour. This tour allowed any individual a chance to see several large sinkholes in the area. This was a car tour that stopped at four different sites. Wayne Jones discussed the geologic ramifications of the project at the largest sinkhole in Thompson Township; the Big Sink. John Crumrine and Jamie Kreglow discussed different conservation practices that were cost shared, and showed the audience a sinkhole structure on the Flat Rock Children's Home property.

- July, 1992. Sinkhole tour for the Cooperative Extension Service state of Ohio members. Approximately 40 people attended a tour in which four sinkholes were seen with a description of the project presented by Jamie Kreglow.

- July, 1992. Sinkhole tour for the Erie Metro Park District cooperators. Twenty individuals attended a tour to find out how sinkholes affect water quality. The tour was directed by Elaine Borchart of the Parks District, and Jamie Kreglow.

- August, 1992. Annual SWCD Summer Supervisors School. A sinkhole tour was given to 45 supervisors and various SWCD staff. A tour of Seneca Caverns was provided to show individuals what the sinkhole area looked like below the ground. A tour of three sinkholes was given to show the impacts of surface water drainage and ground water quality.

- August, 1992. Wastewater Management Committee Public Meeting. 50 area residents attended a meeting designed to explain the results of the septic system survey, educate homeowners on septic system management, and explain how a sinkhole area is quite vulnerable to ground water contamination. Two videos were shown. One to explain how a septic system needs to be maintained and cared for and another tape about the Big Spring Basin project taking place in Iowa.

- September, 1992. A tour was held for the Upper Thames River Authority. Twelve Canadian officials toured the sinkhole area and discussed the possibilities of further research that will be done on the project.

Chapter 9. PITFALLS AND PROBLEMS ENCOUNTERED

9.1 Sinkhole Storm Event Sampling

A major problem encountered was sampling several sinkholes during storm events. Sinkholes all vary by size, shape, watershed area, and location of the sinkhole to the topography of the area. Due to these differences, every sinkhole must be sampled differently and at different times.

One major factor in sampling sinkholes is its watershed size. The smaller the watershed area, the shorter time you'll have to collect a water sample. Other factors are storm event duration and amount, ground cover type, amounts of rainfall for the month, accessibility to the sinkhole, and whether the sinkhole is an overflow outlet for another large sinkhole in the area.

We were unable to consistently grab samples at the five sinkholes to be used in the project. The storm events were either too short in duration and there was not enough water to get to the sinkhole, or the storm event flooded the area making it impossible to get a representative sample. Only once, were we able to get a representative sample from all the sinkholes on the same day. The only way to obtain storm samples in this karst area is to use modified auto samplers.

The type and amount of ground cover affects the time duration and flow of water into the sinkhole. This was most apparent during the extended period of drought we experienced in 1991. We experienced two to three storm events after drought conditions before water actually entered the sinkholes. Other times after normal rainfall periods it would rain once, flood the area, and make sampling at the sinkhole impossible.

Some of the sinkholes were one quarter mile from the nearest road making the sampling duration and procedure too long, and too dangerous (excessive mud on steep slopes) to complete. Two of the sinkholes were overflow outlets for larger sinkholes in the area, but due to the lack of water flow during average storm events, no samples could be collected.

9.2 Dye trace study

9.21 Installing dye trace collection packets in wells

Another area of trial and error was the installation of dye trace collection packets in wells located in Thompson and York Townships. These nylon mesh packets were made in 1"x4"x1/2" and 2"x4"x1/2" sizes. Steel washers were added to the charcoal to increase the weight of the packets so they could be lowered into the well with fishing line. Another device, a hose adaptor collector was used in wells that a dye trace collector packet would not work. This device needed water pumped at 1-3 GPM from the well through a hose for it to work. A dye trace "Bug" was constructed for artesian wells and streams.

The average diameter of the well casing in the area was six inches. Inside the casing a pitless adaptor, a 3/4 to 1 inch water line, and a 3 inch diameter well pump are attached. Sufficient room was available for a dye packet to reach the static water level in most wells. In some wells, the packet would become lodged in the borehole.

Well spacers, installed in the well casing, limited the space available to lower the packet. Other considerations not thought of were that all wells are not drilled in a straight vertical line. This problem, added to the various other obstructions, made some wells impossible to use for the dye trace study.

Wells that could be used for the dye trace collection packets never showed a trace of the dye. None of the wells with this setup showed any traces of dye, yet several of the wells in the same area using the hose adaptor collection device detected dye. This is due to the fact that the charcoal packets in the wells were not down to where the pump was set, and thus no water was flowing through the charcoal. Based on this information, the dye trace collection packets were found to be unsatisfactory.

9.22 Losing Dye Trace Collection Packets

Once the dye trace collection packets were in place, the dye was injected, and packets were collected on a periodic basis to track dye movement. The current of the flowing spring would sometimes sweep the packet away from its bug. People would steal the bugs with packets as well.

The water in some of these artesian wells was very corrosive. Brass fishing swivels were used to attach the packet to the bug. Within one months time, these swivels would fall apart from the corrosion, and we would lose a dye trace packet. This water would even corrode the stainless steel staples used to make the nylon packets that were used. Several different products were used to attach the packets yet the water would corrode almost everything.

9.23 Measuring Dye Amounts From Collection Packets

After collecting the various packets, the charcoal used to absorb dye would be cleaned with a pressurized water hose and removed from the nylon packet. It would then be mixed with an elutant that would remove the dye from the charcoal. At first, the dye could be detected in the elutant with the naked eye. Eventually a fluorometer was needed to detect the dye. This fluorometer is able to detect very minute levels of fluorescein that are undetectable with the naked eye. At times the charcoal could not be cleaned enough to keep the iron and sulfur deposits from interfering with the fluorometer readings. These samples had to be discarded.

Another problem encountered was the elutant that was used. It was similar in chemical characteristics of Draino. It would melt the containers that were used to store the charcoal dye trace sample. We had to use a special bottle provided by the Water Quality Laboratory at Heidelberg College.

9.3 Cropping rotation vs. structure installation

During our first attempts to install sinkhole structures, we noticed that some buffer strips around the structure would not grow properly. They would germinate, but would die off within a couple of weeks. Other buffer strips would grow and establish themselves by fall. The only difference between the two structures were that wheat was grown around the buffer strips that survived. Corn and Soybean crop herbicides were killing the other buffers. These buffers needed to be installed during the wheat crop rotation.

Cropping rotations are a needed item in the farming industry when considering a maximum economic return for the farmers investment. By using a rotation, a farmer can improve the organic matter of the soil which improves yield, reduces the continual need for lime and certain kinds of fertilizer, and reduces soil erosion.

Crop rotations also allow farmers to install certain conservation practices (buffer plantings) that may not grow next to certain crops during their establishment stages. For conservation structures to work effectively, a grass buffer strip or grass/legume combination must be installed before or around the structure. These buffers are very sensitive to certain herbicides during their germination and establishment stage. Therefore, a crop that does not use these herbicides should be grown next to the buffer area.

The crops in Thompson Township that are suitable for planting adjacent to a buffer are canola and wheat. Both crops use very little if any herbicide, and are harvested in the summer. The summer harvest allows the contractor to install the structure and plant the buffer during growing conditions. The buffer is given enough time to establish itself before winter weather moves into the area.

9.4 Weather

Weather variations have had a major impact on project results. The first year of the project was very wet, which made getting into the fields very difficult. The second year was a severe drought year. A drought allows you to get all your work completed, yet nothing will grow. Starting in July, 1992, rainfall for the Thompson Township was above normal.

Despite these adversities, much valid information was obtained from the project. If it weren't for the excessive amounts of rain in 1992, the drought of 1991 could have ruined the dye trace portion of the project. We received enough rain after the dye was injected, to trace dye at least 9 miles from the injection site. The static water levels were significantly lower in

January, 1992, thus making the abundance of rainfall later in 1992 necessary to raise the ground water levels for a successful dye trace program.

9.5 Public Participation In BMP And Dye Trace Project

9.51 Best management practice participation

Several factors affected public participation of the Best Management Practice section of the project. The majority of the landowners were interested in installing BMP's, however, the problem was that over one year of drought in that area had caused decreases in farm income. The lack of income hindered many farmers ability to pay their part of the practice cost share amount.

In 1992 many of the scheduled practices were not installed due to excessive rainfall during the construction season. In 1993, four sinkhole structures were installed which utilized the majority of the cost share money.

9.52 Dye trace participation

Because of the previous dry years, the water table in the area was significantly lower than normal. In 1991, the dye trace project was schedule to begin. It was postponed until 1992 due to the lack of rainfall and low static water levels. During the dye trace project, several landowners were not willing to use the hose type collection devices for fear of their well running dry. By the time we received the rain and the static levels returned to normal, the dye had already passed into Sandusky County.

9.53 Optical Brightener Study

We publicized the optical brightener study and hoped people would contact us to participate. Participation was almost nonexistent. We needed to be more aggressive and approach homeowners directly to conduct the study.

Chapter 10. CONCLUSIONS

Documented ground water quality problems were obtained in March, 1990 through the county-wide well water testing program that indicated that the nitrate levels found in Thompson Township were over two times the county average. Also, 35 % of the wells tested for bacteria in Thompson Township were found to be unsafe. Because of these results, this project was initiated to characterize the ground water flow system and to implement Best Management Practices in an effort to improve both surface and ground water quality.

Hydrogeologic activities included water level monitoring, a fracture trace analysis, various borehole investigations, and a dye trace study. Results from the water level surveys indicated that a linear potentiometric low exists extending from the center of the township to the northeast. Geophysical surveys conducted by Drane (1993) have verified that a cavern or void exists at depth at the location of the potentiometric low. Rapid increases in the water levels also support the conclusion that conduit flow is very prevalent within Thompson Township.

Results of the fracture trace analysis indicate that two major orientations of fractures exist within Thompson Township. The major trend is in a northeast direction, with a conjugate set oriented in a northwesterly direction. Ground reconnaissance and borehole investigations verified the existence and orientation of these fractures.

A dye trace study was initiated on May 11, 1992 in order to verify the direction of ground water flow and to obtain ground water travel times through the karst limestone. Results from the dye trace showed that the ground water was traveling towards the potentiometric low and then to the northeast as indicated on the water table maps. Ground water travel times of 400 to 500 feet per day were obtained. Dye was detected in samples collected up to eight miles from the point of dye injection at the Big Sink.

Knowing the direction and rate of ground water flow enables representative monitoring of any changes in ground water quality as a result of activities at the surface. Various sampling frequencies were utilized to determine trends and variations in the ground water quality. It appears that precipitation, or the lack thereof, was the biggest factor in causing variations in the ground water quality during the life of this project.

Accessibility to the surface water sites at the four sinkholes during storm events, precluded the collection of a statistically valid number of grab samples. Auto-samplers should have been used and will be during further work in this area.

It is too soon to determine the direct impact this project has had on improving the ground water quality in Thompson Township. Best Management Practices have been installed within Thompson Township covering approximately 94 acres. These BMPs alone should prevent approximately 508 tons of sediment from eroding into the sinkholes each year. Along with the sediment, soluble contaminants such as nitrates will be reduced from the ground water system through surface application reductions and the development of farm Conservation Plans. These plans have been written for eight farms within Thompson Township.

Work completed by the Wastewater Management Committee has been to increase knowledge and awareness to the need of proper maintenance of one's septic system. Twenty-five septic systems were inspected and pumped as part of a cost share program.

Education was a very important component during this project. Eight public meetings or tours were given. Twenty articles appeared in the local newspapers describing the project and promoting the tours and meetings. Five abstracts and/or reports were written which resulted in six technical presentations. Three brochures were also written and distributed to the residents of Thompson Township.

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APPENDIX A

STATIC WATER LEVEL DATA

SENECA COUNTY THOMPSON TOWNSHIP
JULY, 1990

WELL I.D.	SURFACE ELEVATION	STATIC WATER LEVEL	WATER ELEVATION
2.0	785	28.35	756.65
3.0	785	21.20	763.80
4.0	786	24.00	762.00
4.1	796	31.05	764.95
5.0	786	16.70	769.30
6.0	783	26.50	756.50
7.0	800	48.88	751.12
8.0	783	37.44	745.56
9.0	789	39.14	749.86
10.0	786	91.31	694.69
11.0	786	89.50	696.50
11.1	787	86.44	700.56
12.0	791	100.58	690.42
12.1	791	95.00	696.00
13.0	791	88.46	702.54
14.0	785	98.82	686.18
15.0	772	96.64	675.36
16.0	765	97.23	667.77
17.0	770	88.20	681.80
18.0	770	82.93	687.07
18.5	770	92.13	677.87
18.5	770		
19.5	775	94.17	680.83
20.0	780	34.96	745.04
21.0	779	81.96	697.04
22.0	776	32.42	743.58
23.0	783	27.68	755.32
24.1	783	45.18	737.82
26.0	787	30.34	756.66
27.0	787	17.69	769.31
28.0	793	66.68	726.32
29.0	793	110.38	682.62
30.0	791	105.02	685.98
33.0	798	97.34	700.66
33.5	798	115.18	682.82
33.6	798	117.93	680.07
34.0	800	58.56	741.44
35.0	802	119.00	683.00
37.0	801	101.72	699.28
38.0	799	93.84	705.16
39.0	796	88.20	707.80
41.0	794	79.86	714.14
42.0	791	98.34	692.66
43.0	795	105.22	689.78
44.0	794	111.90	682.10

SENECA COUNTY THOMPSON TOWNSHIP
JULY, 1990

WELL I.D.	SURFACE ELEVATION	STATIC WATER LEVEL	WATER ELEVATION
45.0	795	16.67	778.33
46.0	805	8.27	796.73
47.0	803	6.91	796.09
48.0	803	3.95	799.05
49.0	806	7.83	798.17
49.5	805	39.60	765.40
50.0	786		
55.0	794	47.83	746.17
55A	794	49.63	744.37
55B	794	49.27	744.73
55D	794	68.55	725.45
55E	794	87.52	706.48
56.1	795	112.53	682.47
57.0	791	96.73	694.27
57A	790	94.41	695.59
58.0	791	91.08	699.92
59.0	792		
59C	792	85.92	706.08
60.0	792	86.54	705.46
61.0	793	70.82	722.18
63.1	795	66.82	728.18
63.0	793		
64.0	798	58.45	739.55
65.0	796	50.63	745.37
66.0	799	53.42	745.58
67.0	801	60.38	740.62
68.0	800	60.38	739.62
69.0	800	80.62	719.38
69.1	795	76.85	718.15
70.0	798	31.92	766.08
71.1	798	31.60	766.40
71.2	798	32.22	765.78
72.0	811	70.35	740.65
72A	805		
73.0	795	12.30	782.70
74.0	800	19.80	780.20
75.0	796	19.30	776.70
75.1	793	25.50	767.50
76.0	793	20.60	772.40
76.1	795	20.40	774.60
78.0	800	14.45	785.55
80.0	796	11.60	784.40
81.0	810	24.40	785.60
82.0	802	19.00	783.00
83.0	800	21.90	778.10

SENECA COUNTY THOMPSON TOWNSHIP
JULY, 1990

WELL I.D.	SURFACE ELEVATION	STATIC WATER LEVEL	WATER ELEVATION
83.1	799	30.90	768.10
84.0	801	45.85	755.15
86.0	806	66.68	739.32
87.0	810	72.75	737.25
88A	814		
89.0	805	111.68	693.32
89.1	800	108.70	691.30
89.2	804	81.58	722.42
90.0	804	115.78	688.22
90.1	801	115.98	685.02
91A	809		
92.0	806	34.18	771.82
92.5	805		
93.0	809	25.98	783.02
93.2	815	30.16	784.84
93.3	802		
93.4	813	53.21	759.79
93.8	827	71.82	755.18
94.0	808	7.91	800.09
95.0	810	17.27	792.73
96.0	808	31.90	776.10
97.0	803	91.80	711.20
98.0	804	74.90	729.10
99.0	811	78.16	732.84
100.0	805	60.50	744.50
100.1	810	78.87	731.13
101.0	820		
101.1	819	10.20	808.80
102.0	821	14.00	807.00
102.1	813	9.00	804.00
103.0	840	30.90	809.10
104.0	835	29.40	805.60
105.0	835	22.90	812.10
106.0	835	18.30	816.70
107.1	833	18.05	814.95
108.0	833	18.20	814.80
110.0	834	46.05	787.95
111.0	838	31.65	806.35
113.0	838	62.01	775.99
113A	814		
114.0	826	57.15	768.85
115.0	835	61.70	773.30
116.0	841	71.80	769.20
117.0	829	35.23	793.77
118.0	840	21.22	818.78

SENECA COUNTY THOMPSON TOWNSHIP
JULY, 1990

WELL I.D.	SURFACE ELEVATION	STATIC WATER LEVEL	WATER ELEVATION
120.0	845	39.00	806.00
121.0	845	38.80	806.20
~~123.0~~	~~858~~	~~64.85~~	~~793.15~~
124.0	840		
125.0	840	68.35	771.65
126.0	842	20.30	821.70
~~127.0~~	~~845~~	~~21.70~~	~~823.30~~
127.1	845	23.55	821.45
128.0	855	6.31	848.69
131.0	853	8.71	844.29
133.0	868	9.30	858.70

SENECA COUNTY THOMPSON TOWNSHIP
NOVEMBER, 1990

WELL I.D.	SURFACE ELEVATION	STATIC WATER LEVEL	WATER ELEVATION
2.0	785		
3.0	785		
4.0	786		
4.1	796		
5.0	786		
6.0	783		
7.0	800	42.36	757.64
8.0	783	30.69	752.31
9.0	789	33.37	755.63
10.0	786	85.9	700.1
11.0	786	84.88	701.12
11.1	787	83.37	703.63
12.0	791		
12.1	791		
13.0	791	84.49	706.51
14.0	785	93.65	691.35
15.0	772	91.75	680.25
16.0	765	91.9	673.1
17.0	770		
18.0	770		
18.5	770	86.25	683.75
18.5	770	85.6	684.4
19.5	775	89.3	685.7
20.0	780	35.8	744.2
21.0	779		
22.0	776	31.35	744.65
23.0	783		
24.1	783		
26.0	787		
27.0	787	12.4	774.6
28.0	793		
29.0	793	105.35	687.65
30.0	791	99.3	691.7
33.0	798	83	715
33.5	798		
33.6	798		
34.0	800	58.7	741.3
35.0	802	113	689
37.0	801		
38.0	799	79.45	719.55
39.0	796	65.55	730.45
41.0	794	54.8	739.2
42.0	791	118.9	672.1
43.0	795	98.45	696.55
44.0	794	107.7	686.3

SENECA COUNTY THOMPSON TOWNSHIP
NOVEMBER, 1990

WELL I.D.	SURFACE ELEVATION	STATIC WATER LEVEL	WATER ELEVATION
45.0	795	15.25	779.75
46.0	805	5.3	799.7
47.0	803		
48.0	803		
49.0	806	7.1	798.9
49.5	805	57.3	747.7
50.0	786	93.5	692.5
55.0	794		
55A	794		
55B	794		
55D	794	65.98	728.02
55E	794	82.78	711.22
56.1	795		
57.0	791	90.37	700.63
57A	790		
58.0	791	86.61	704.39
59.0	792	82.15	709.85
59C	792		
60.0	792	82.25	709.75
61.0	793		
63.1	795		
63.0	793	62.87	730.13
64.0	798	54.36	743.64
65.0	796	45.3	750.7
66.0	799	46.39	752.61
67.0	801	56.02	744.98
68.0	800	55.35	744.65
69.0	800		
69.1	795	62.37	732.63
70.0	798	25.2	772.8
71.1	798	24.76	773.24
71.2	798	25.25	772.75
72.0	811	55.66	755.34
72A	805	53.65	751.35
73.0	795		
74.0	800		
75.0	796		
75.1	793		
76.0	793		
76.1	795		
78.0	800		
80.0	796		
81.0	810		
82.0	802		
83.0	800		

SENECA COUNTY THOMPSON TOWNSHIP
NOVEMBER, 1990

WELL I.D.	SURFACE ELEVATION	STATIC WATER LEVEL	WATER ELEVATION
83.1	799		
84.0	801		
~~86.0~~	~~806~~		
87.0	810	57.87	752.13
88A	814	34.6	779.4
89.0	805		
~~89.1~~	~~800~~	~~103.51~~	~~696.49~~
89.2	804	69.75	734.25
90.0	804	108.12	695.88
90.1	801		
91A	809	103.1	705.9
92.0	806	30.7	775.3
92.5	805	46.1	758.9
93.0	809	32.78	776.22
93.2	815	52.68	762.32
93.3	802	49.45	752.55
93.4	813	34.75	778.25
93.8	827	53.73	773.27
94.0	808	8.23	799.77
95.0	810	12.55	797.45
96.0	808	20.2	787.8
97.0	803	79.8	723.2
98.0	804	58.03	745.97
99.0	811	61.12	749.88
100.0	805	60.82	744.18
100.1	810		
101.0	820		
101.1	819		
102.0	821		
102.1	813		
103.0	840		
104.0	835		
105.0	835		
106.0	835		
107.1	833		
108.0	833		
110.0	834	23.76	810.24
111.0	838	31.25	806.75
113.0	838	43.9	794.1
113A	814	39.41	774.59
114.0	826	39.15	786.85
115.0	835	44.71	790.29
116.0	841	52.84	788.16
117.0	829	46.85	782.15
118.0	840		

SENECA COUNTY THOMPSON TOWNSHIP
NOVEMBER, 1990

WELL I.D.	SURFACE ELEVATION	STATIC WATER LEVEL	WATER ELEVATION
120.0	845		
121.0	845		
123.0	858		
~~124.0~~	~~840~~		
125.0	840	50.51	789.49
126.0	842		
127.0	845		
~~127.1~~	~~845~~		
128.0	855		
131.0	853		
133.0	868		

SENECA COUNTY THOMPSON TOWNSHIP
MARCH, 1991

WELL I.D.	SURFACE ELEVATION	STATIC WATER LEVEL	WATER ELEVATION
2.0	785		
3.0	785		
4.0	786		
4.1	796		
5.0	786		
6.0	783		
7.0	800	25.55	774.45
8.0	783	14.95	768.05
9.0	789	16.57	772.43
10.0	786	57.8	728.2
11.0	786	56.8	729.2
11.1	787		
12.0	791		
12.1	791		
13.0	791	56.17	734.83
14.0	785	65.3	719.7
15.0	772	62.7	709.3
16.0	765	62	703
17.0	770		
18.0	770		
18.5	770	56.35	713.65
18.5	770		
19.5	775	59.5	715.5
20.0	780	27.75	752.25
21.0	779		
22.0	776	25.1	750.9
23.0	783		
24.1	783		
26.0	787		
27.0	787	10	777
28.0	793	19.5	773.5
29.0	793	75.15	717.85
30.0	791	62.25	728.75
33.0	798	64.1	733.9
33.5	798		
33.6	798		
34.0	800	60.25	739.75
35.0	802	83.5	718.5
37.0	801		
38.0	799		799
39.0	796	53.8	742.2
41.0	794	42	752
42.0	791		
43.0	795		
44.0	794	78.5	715.5

SENECA COUNTY THOMPSON TOWNSHIP
MARCH, 1991

WELL I.D.	SURFACE ELEVATION	STATIC WATER LEVEL	WATER ELEVATION
45.0	795	14.1	780.9
46.0	805	4.4	800.6
~~47.0~~	~~803~~		
48.0	803		
49.0	806	5.1	800.9
49.5	805	30.3	774.7
~~50.0~~	~~786~~	~~64.35~~	~~721.65~~
55.0	794		
55A	794		
55B	794		
55D	794	47.42	746.58
55E	794	55.22	738.78
56.1	795		
57.0	791	63.1	727.9
57A	790		
58.0	791	58.3	732.7
59.0	792	53.58	738.42
59C	792		
60.0	792	53.75	738.25
61.0	793		
63.1	795		
63.0	793	52.52	740.48
64.0	798	40.43	757.57
65.0	796	28.43	767.57
66.0	799		
67.0	801	41.07	759.93
68.0	800	39.8	760.2
69.0	800	46.6	753.4
69.1	795	40.32	754.68
70.0	798	11.18	786.82
71.1	798	9.87	788.13
71.2	798	10.54	787.46
72.0	811	29.95	781.05
72A	805	28.25	776.75
73.0	795		
74.0	800		
75.0	796		
75.1	793		
76.0	793		
76.1	795		
78.0	800		
80.0	796		
81.0	810		
82.0	802		
83.0	800		

SENECA COUNTY THOMPSON TOWNSHIP
MARCH, 1991

WELL I.D.	SURFACE ELEVATION	STATIC WATER LEVEL	WATER ELEVATION
83.1	799		
84.0	801		
86.0	806	27.05	778.95
87.0	810	32.55	777.45
88A	814	19.8	794.2
89.0	805		
89.1	800	78.05	721.95
89.2	804	49.35	754.65
90.0	804	81.4	722.6
90.1	801		
91A	809	75.3	733.7
92.0	806	25.25	780.75
92.5	805		
93.0	809	24.25	784.75
93.2	815	34	781
93.3	802		
93.4	813	17.15	795.85
93.8	827	37.2	789.8
94.0	808	7.3	800.7
95.0	810	9.7	800.3
96.0	808	12.3	795.7
97.0	803	59.05	743.95
98.0	804	34.93	769.07
99.0	811	38.62	772.38
100.0	805	38.62	766.38
100.1	810		
101.0	820		
101.1	819		
102.0	821		
102.1	813		
103.0	840		
104.0	835		
105.0	835		
106.0	835		
107.1	833		
108.0	833		
110.0	834	20.71	813.29
111.0	838	21.65	816.35
113.0	838	31.3	806.7
113A	814	20.88	793.12
114.0	826	23.02	802.98
115.0	835	31.88	803.12
116.0	841	31.02	809.98
117.0	829	29.3	799.7
118.0	840		

SENECA COUNTY THOMPSON TOWNSHIP
MARCH, 1991

WELL I.D.	SURFACE ELEVATION	STATIC WATER LEVEL	WATER ELEVATION
120.0	845		
121.0	845		
123.0	858		
~~124.0~~	~~840~~	~~35.28~~	~~804.72~~
125.0	840	36.82	803.18
126.0	842		
127.0	845		
~~127.1~~	~~845~~		
128.0	855		
131.0	853		
133.0	868		

SENECA COUNTY THOMPSON TOWNSHIP
NOVEMBER, 1991

WELL I.D.	SURFACE ELEVATION	STATIC LEVEL	WATER ELEVATION
2.0	785	27.9	757.1
3.0	785	24.1	760.9
4.0	786	27.4	758.6
4.1	796	18.7	777.3
5.0	786		
6.0	783		
7.0	800	65.36	734.64
8.0	783	51.95	731.05
9.0	789	53.8	735.2
10.0	786	107.28	678.72
11.0	786	105.35	680.65
11.1	787	104.27	682.73
12.0	791		
12.1	791		
13.0	791	104.42	686.58
14.0	785	116.25	668.75
15.0	772	121	651
16.0	765	120.45	644.55
17.0	770	109	661
18.0	770		
18.5	770		
18.5	770	114.2	655.8
19.5	775	117	658
20.0	780	48.2	731.8
21.0	779		
22.0	776	45.5	730.5
23.0	783		
24.1	783		
26.0	787		
27.0	787	50	737
28.0	793		
29.0	793	132	661
30.0	791	127.5	663.5
33.0	798	116.8	681.2
33.5	798		
33.6	798		
34.0	800	114	686
35.0	802	142.33	659.67
37.0	801		
38.0	799	109.45	689.55
39.0	796	107.17	688.83
41.0	794	33.2	760.8
42.0	791	96.6	694.4
43.0	795	102	693
44.0	794	112.5	681.5

SENECA COUNTY THOMPSON TOWNSHIP
NOVEMBER, 1991

WELL I.D.	SURFACE ELEVATION	STATIC LEVEL	WATER ELEVATION
45.0	795	27	768
46.0	805	9.25	795.75
47.0	803		
48.0	803		
49.0	806	13	793
49.5	805	73.5	731.5
50.0	786	122	664
55.0	794		
55A	794		
55B	794		
55D	794		
55E	794	98.1	695.9
56.1	795		
57.0	791	113.77	677.23
57A	790		
58.0	791	106.69	684.31
59.0	792	98.49	693.51
59C	792		
60.0	792	102.29	689.71
61.0	793		
63.1	795		
63.0	793		
64.0	798	71.69	726.31
65.0	796		
66.0	799	64.78	734.22
67.0	801	73.73	727.27
68.0	800	71.02	728.98
69.0	800		
69.1	795	98.15	696.85
70.0	798	52.12	745.88
71.1	798	51.63	746.37
71.2	798	52.12	745.88
72.0	811	92.45	718.55
72A	805	89.22	715.78
73.0	795	21.7	773.3
74.0	800		
75.0	796	22.6	773.4
75.1	793		
76.0	793	22.3	770.7
76.1	795	25	770
78.0	800	24.8	775.2
80.0	796	21.9	774.1
81.0	810	39.6	770.4
82.0	802	41	761
83.0	800	44.7	755.3

SENECA COUNTY THOMPSON TOWNSHIP
NOVEMBER, 1991

WELL I.D.	SURFACE ELEVATION	STATIC LEVEL	WATER ELEVATION
83.1	799	52	747
84.0	801	55.4	745.6
86.0	806	87.6	718.4
87.0	810	93.7	716.3
88A	814	89.12	724.88
89.0	805	134.23	670.77
89.1	800	129.42	670.58
89.2	804	100.52	703.48
90.0	804	138.81	665.19
90.1	801		
91A	809	134	675
92.0	806	74.9	731.1
92.5	805	93	712
93.0	809	68	741
93.2	815	65	750
93.3	802	96.5	705.5
93.4	813	82	731
93.8	827	101	726
94.0	808	14	794
95.0	810	26.5	783.5
96.0	808	45.5	762.5
97.0	803	114.25	688.75
98.0	804	98.17	705.83
99.0	811	101.32	709.68
100.0	805		
100.1	810		
101.0	820	21.3	798.7
101.1	819		
102.0	821	24.1	796.9
102.1	813		
103.0	840	49.8	790.2
104.0	835		
105.0	835	37.7	797.3
106.0	835		
107.1	833	37	796
108.0	833	39.6	793.4
110.0	834	73.3	760.7
111.0	838	71.95	766.05
113.0	838	103.47	734.53
113A	814	92.25	721.75
114.0	826	94.43	731.57
115.0	835	90.4	744.6
116.0	841	102.34	738.66
117.0	829	95.6	733.4
118.0	840	40.5	799.5

SENECA COUNTY THOMPSON TOWNSHIP
NOVEMBER, 1991

WELL I.D.	SURFACE ELEVATION	STATIC LEVEL	WATER ELEVATION
120.0	845	40.5	804.5
121.0	845	40.7	804.3
~~123.0~~	~~858~~	~~92.5~~	~~765.5~~
124.0	840	94.15	745.85
125.0	840	96.57	743.43
126.0	842	40	802
~~127.0~~	~~845~~	~~48.2~~	~~796.8~~
127.1	845	45.5	799.5
128.0	855		855
131.0	853		853
133.0	868	16.8	851.2

SENECA COUNTY THOMPSON TOWNSHIP
APRIL, 1993

WELL I.D.	SURFACE ELEVATION	STATIC WATER LEVEL	WATER ELEVATION
2.0	785		
3.0	785		
4.0	786		
4.1	796		
5.0	786		
6.0	783		
7.0	800	20.11	779.89
8.0	783	8.68	774.32
9.0	789	17.50	771.50
10.0	786	38.80	747.20
11.0	786	37.50	748.50
11.1	787		
12.0	791	50.15	740.85
12.1	791		
13.0	791		
14.0	785	46.30	738.70
15.0	772	43.05	728.95
16.0	765	43.20	721.80
17.0	770		
18.0	770		
18.5	770	36.82	733.18
18.5	770		
19.5	775	40.75	734.25
20.0	780	20.15	759.85
21.0	779		
22.0	776		
23.0	783		
24.1	783		
26.0	787		
27.0	787	10.22	776.78
28.0	793		
29.0	793	56.30	736.70
30.0	791	51.25	739.75
33.0	798	52.10	745.90
33.5	798		
33.6	798		
34.0	800	47.10	752.90
35.0	802	64.60	737.40
37.0	801		
38.0	799	48.25	750.75
39.0	796	38.60	757.40
41.0	794	28.55	765.45
42.0	791		
43.0	795		
44.0	794	59.70	734.30

SENECA COUNTY THOMPSON TOWNSHIP
APRIL, 1993

WELL I.D.	SURFACE ELEVATION	STATIC WATER LEVEL	WATER ELEVATION
45.0	795	13.80	781.20
46.0	805	4.80	800.20
47.0	803		
48.0	803		
49.0	806	5.30	800.70
49.5	805	65.40	739.60
50.0	786	45.00	741.00
55.0	794		
55A	794	16.90	777.10
55B	794		
55D	794	37.80	756.20
55E	794		
56.1	795	57.85	737.15
57.0	791	46.16	744.84
57A	790	44.65	745.35
58.0	791	40.05	750.95
59.0	792		
59C	792		
60.0	792		
61.0	793	33.30	759.70
63.1	795		
63.0	793	28.55	764.45
64.0	798		
65.0	796	17.56	778.44
66.0	799		
67.0	801	29.40	771.60
68.0	800	26.45	773.55
69.0	800	31.10	768.90
69.1	795	35.15	759.85
70.0	798	6.03	791.97
71.1	798	5.22	792.78
71.2	798		
72.0	811	18.80	792.20
72A	805		
73.0	795		
74.0	800		
75.0	796		
75.1	793		
76.0	793		
76.1	795		
78.0	800		
80.0	796		
81.0	810		
82.0	802		
83.0	800		

SENECA COUNTY THOMPSON TOWNSHIP
APRIL, 1993

WELL I.D.	SURFACE ELEVATION	STATIC WATER LEVEL	WATER ELEVATION
83.1	799		
84.0	801		
~~86.0~~	~~806~~	~~17.02~~	~~788.98~~
87.0	810	21.08	788.92
88A	814		
89.0	805	58.26	746.74
~~89.1~~	~~800~~	~~59.75~~	~~740.25~~
89.2	804		
90.0	804	82.28	721.72
90.1	801	61.60	739.40
91A	809	70.35	738.65
92.0	806	24.10	781.90
92.5	805	20.56	784.44
93.0	809	19.05	789.95
93.2	815	30.40	784.60
93.3	802	18.90	783.10
93.4	813	12.15	800.85
93.8	827		
94.0	808	7.50	800.50
95.0	810	9.35	800.65
96.0	808	8.00	800.00
97.0	803	44.10	758.90
98.0	804	22.46	781.54
99.0	811	25.81	785.19
100.0	805	25.61	779.39
100.1	810		
101.0	820		
101.1	819		
102.0	821		
102.1	813		
103.0	840		
104.0	835		
105.0	835		
106.0	835		
107.1	833		
108.0	833		
110.0	834	18.49	815.51
111.0	838	16.89	821.11
113.0	838	27.56	810.44
113A	814		
114.0	826	17.88	808.12
115.0	835	28.40	806.60
116.0	841	26.68	814.32
117.0	829	24.52	804.48
118.0	840	5.70	834.30

SENECA COUNTY THOMPSON TOWNSHIP
APRIL, 1993

WELL I.D.	SURFACE ELEVATION	STATIC WATER LEVEL	WATER ELEVATION
120.0	845	36.75	808.25
121.0	845		
123.0	858		
124.0	840		
125.0	840	32.82	807.18
126.0	842		
127.0	845		
127.1	845		
128.0	855		
131.0	853		
133.0	868		

APPENDIX B

WELL WATER QUALITY DATA

SENECA NPS WATER QUALITY DATA

NAME	DATE	NO23	NO2	NH3	CL	SO4	COND	SRP	SIO2	TRISCR	ALASCR
Decker, C	3/1/91	8.86	−0.020	0.006	16.80	73.30	680	0.007	7.52		
Myer	3/1/91	0.13	0.017	0.091	23.60	−9999.00	2268	0.000	15.57		
Kimberlain	3/1/91	8.10	−0.003	0.005	14.80	64.10	677	−0.001	8.40		
Pocock	3/1/91	4.10	−0.005	0.000	12.00	340.20	1070	−0.001	8.95		
Weasner	3/1/91	3.22	−0.004	−0.003	20.10	126.20	856	−0.001	10.55		
Norman	3/1/91	2.74	−0.004	0.002	26.00	110.40	799	0.001	9.30		
Good	3/1/91	3.54	−0.004	−0.002	12.40	268.60	916	−0.001	7.56		
Krueger	3/1/91	1.87	−0.003	0.003	45.40	90.60	833	0.000	10.92		
Henney	3/1/91	2.12	−0.004	0.003	12.70	568.80	1274	0.003	6.97		
Ringholz	3/1/91	6.21	−0.004	0.002	16.80	75.50	704	0.001	9.44		
Williamson	3/1/91	2.06	−0.003	0.000	27.70	295.90	1111	0.002	9.24		
Warner	3/1/91	4.32	−0.004	0.006	14.10	562.30	1331	0.000	7.58		
Stone Quarry	3/1/91	0.80	−0.002	−0.002	20.80	685.90	1413	0.002	6.18		
Childrens Home	3/1/91	13.02	0.000	0.565	83.90	102.20	1013	0.026	7.69		
Mager	3/1/91	13.72	0.005	0.007	16.70	118.80	834	0.000	9.07		
Snyder	3/1/91	12.65	−0.004	0.000	56.90	151.60	956	0.100	7.42		
Smith	3/1/91	5.79	−0.003	−0.002	12.60	154.00	737	0.006	6.96		
Hillman	3/1/91	0.08	−0.002	0.136	3.40	211.90	925	0.001	11.36		
Horns C.S.	3/1/91	0.08	−0.004	0.095	16.10	939.80	1862	−0.002	15.00		
Wollenslegel	3/1/91	8.49	−0.002	−0.001	17.40	64.00	661	0.005	8.32		
Stone Quarry	3/1/91	3.45	0.015	0.045	12.50	199.60	653	0.002	3.68		
Cook	3/1/91	0.08	−0.005	−0.002	13.10	223.90	998	−0.002	9.64		
Decker, K	3/1/91	2.52	−0.003	−0.001	8.80	128.00	686	−0.002	7.60		
Zilch	3/1/91	0.26	−0.004	−0.003	5.60	338.80	1091	−0.002	8.36		
Rice	3/1/91	0.08	−0.004	−0.002	9.90	135.40	800	0.000	9.21		
Butz	3/1/91	9.91	−0.002	0.005	18.20	69.90	711	−0.001	8.46		
Kuhn	3/1/91	2.54	−0.001	0.046	16.00	44.00	235	0.028	2.18		
Nearhood	3/1/91	0.11	−0.002	−0.002	20.40	79.60	601	0.003	10.90		
Williams	3/1/91	1.34	0.020	0.005	55.10	157.80	1024	0.000	8.30		
Smith	3/1/91	11.67	−0.003	−0.002	20.60	81.40	844	0.004	8.05		
Gross	3/1/91	0.10	0.001	0.007	8.90	518.70	1290	0.001	8.01		
Reau	3/1/91	0.50	−0.004	0.002	32.00	276.20	1144	0.001	9.89		
Zieber	3/1/91	4.03	−0.004	−0.001	14.40	517.40	1300	0.000	8.22		
Koser	3/1/91	0.55	0.006	0.005	15.10	956.40	1764	0.003	7.48		
Hintz	3/1/91	3.99	−0.003	0.000	23.50	235.70	1013	0.001	9.46		
Alt	3/1/91	0.52	−0.004	0.023	10.00	−9999.00	1665	−0.002	18.99		
Meyer	3/1/91	0.06	−0.003	0.208	6.80	689.80	1374	0.001	8.04		
Smith	3/1/91	0.08	−0.001	0.121	45.20	−9999.00	2111	0.000	19.68		
Miller	3/1/91	4.78	0.010	0.044	8.80	82.50	487	0.023	6.61		

SENECA NPS WATER QUALITY DATA

NAME	DATE	NO23	NO2	NH3	CL	SO4	COND	SRP	SIO2	TRISCR	ALASCR
Henney	4/22/91	1.65	−0.009	0.015	12.70	510.80	1255	0.009	7.07	0.03	0.07
Miller	4/22/91	3.66	−0.004	0.019	9.90	109.50	636	0.042	7.82	1.11	0.11
Horns C.S.	4/22/91	0.02	−0.007	0.100	18.80	533.00	1468	0.005	18.01	0.02	0.03
Krueger	4/22/91	2.36	0.001	0.017	61.70	94.10	891	0.004	11.19	0.02	0.02
Zieber	4/22/91	3.71	−0.006	0.015	14.60	454.90	1170	0.004	8.32	0.02	0.03
Snyder	4/22/91	11.04	−0.004	0.012	60.00	141.00	953	0.084	6.89	0.02	0.04
Good	4/22/91	3.00	−0.006	0.014	12.90	296.40	944	0.005	7.72	0.03	0.03
Gross	4/22/91	0.08	−0.003	0.021	8.20	509.30	1293	0.003	8.21	0.02	0.03
Ringholz	4/22/91	5.11	−0.009	0.017	16.70	77.60	695	0.006	9.52	0.06	0.02
Koser	4/22/91	0.05	−0.007	0.072	16.20	1054.50	1973	0.013	7.63	0.13	0.19
Meyer	4/22/91	0.06	−0.004	0.222	6.80	638.00	1365	0.004	8.13	0.11	0.03
Pocock	4/22/91	3.94	−0.006	0.016	12.00	301.70	1082	0.003	9.02	0.02	0.02
Stone quarry	4/22/91	0.54	−0.007	0.016	18.90	686.90	1401	0.011	6.44	0.02	0.05
Williams	4/22/91	0.20	−0.001	0.020	63.20	135.70	1029	0.002	8.35	0.02	0.02
Smith	4/22/91	4.92	−0.004	0.013	12.90	176.00	665	0.003	6.87	0.04	0.06
Alt	4/22/91	0.11	−0.008	0.699	9.90	−9999.00	2839	0.004	25.67	0.14	0.03

NAME	DATE	NO23	NO2	NH3	CL	SO4	COND	SRP	SIO2	TRISCR	ALASCR
Henney	5/8/91	1.42	−0.008	−0.006	12.70	562.40	1300	0.006	7.32	0.03	0.00
Miller	5/8/91	5.17	−0.007	−0.005	11.60	98.80	628	0.043	8.00	0.94	0.10
Horns C.S.	5/8/91	0.07	−0.009	0.072	15.30	873.40	1858	0.003	15.39	0.01	0.00
Krueger	5/8/91	2.63	−0.010	−0.007	63.70	85.50	921	−0.002	11.93	0.01	0.00
Zieber	5/8/91	3.73	−0.007	0.006	15.50	473.70	1181	0.001	8.17	0.02	0.00
Snyder	5/8/91	9.97	−0.005	−0.006	60.50	147.60	1001	0.093	7.56	0.01	0.00
Good	5/8/91	2.83	−0.009	0.008	12.90	308.00	930	0.000	7.85	0.02	0.00
Gross	5/8/91	0.10	0.000	−0.001	8.30	505.10	1303	0.000	8.63	0.01	0.00
Ringholz	5/8/91	5.19	−0.010	−0.008	16.00	71.10	699	−0.001	9.93	0.02	0.00
Koser	5/8/91	0.06	−0.008	0.043	16.50	−9999.00	1998	0.004	8.10	0.11	0.30
Meyer	5/8/91	0.02	−0.006	0.228	6.80	640.40	1351	0.001	8.14	0.08	0.00
Pocock	5/8/91	4.41	−0.011	−0.008	11.80	329.40	1071	−0.001	9.57	0.01	0.00
Stone quarry	5/8/91	0.47	−0.008	−0.009	18.90	671.70	1440	0.002	6.76	0.02	0.00
Williams	5/8/91	0.18	−0.007	−0.006	65.40	145.80	1069	−0.005	8.85	0.02	0.00
Smith	5/8/91	4.58	−0.008	0.001	12.20	189.70	794	0.002	7.27	0.03	0.00
Alt	5/8/91	0.02	−0.013	0.877	10.20	−9999.00	3084	0.003	22.51	0.01	0.00

NAME	DATE	NO23	NO2	NH3	CL	SO4	COND	SRP	SIO2	TRISCR	ALASCR
Henney	6/3/91	1.35	0.011	−0.010	11.80	585.10	1333	0.005	7.08	0.03	0.05
Miller	6/3/91	12.61	0.093	0.047	12.10	87.70	609	0.035	8.27	13.50	1.84
Horns C.S.	6/3/91	0.02	0.013	0.089	21.70	636.20	1637	0.001	17.91	0.02	0.04

SENECA NPS WATER QUALITY DATA

Krueger	6/3/91	4.66	0.013	−0.007	65.00	81.30	909	0.000	11.25	0.01	0.02
Zieber	6/3/91	3.60	0.009	−0.016	14.40	481.90	1289	0.001	8.14	0.02	0.02
Snyder	6/3/91	8.86	0.010	−0.016	63.20	145.50	1018	0.100	7.80	0.02	0.03
Good	6/3/91	2.80	0.007	−0.010	12.40	334.90	1023	0.000	7.42	0.03	0.02
Gross	6/3/91	0.19	0.011	−0.009	7.90	468.10	1268	−0.002	8.18	0.02	0.02
Ringholz	6/3/91	4.96	0.007	0.027	16.50	70.20	706	0.001	9.51	0.02	0.02
Koser	6/3/91	0.04	0.010	0.036	16.60	−9999.00	1009	0.033	7.84	0.01	0.02
Meyer	6/3/91	0.06	0.008	0.168	6.50	660.30	1395	0.000	8.22	0.10	0.02
Pocock	6/3/91	4.28	0.008	−0.015	11.60	332.20	1098	−0.001	9.22	0.02	0.02
Stone quarry	6/3/91	0.60	0.010	−0.010	18.30	661.30	1428	0.007	6.47	0.02	0.04
Williams	6/3/91	0.17	0.012	−0.005	63.90	146.30	1043	−0.002	8.34	0.02	0.02
Smith	6/3/91	4.68	0.006	−0.012	12.80	198.90	799	0.006	6.91	0.03	0.04
Alt	6/3/91	0.04	0.007	0.670	10.00	−9999.00	1538	0.003	25.29	0.02	0.01

NAME	DATE	NO23	NO2	NH3	CL	SO4	COND	SRP	SIO2	TRISCR	ALASCR
Henney	7/8/91	1.21	−0.003	0.001	13.10	533.70	1271	−0.005	7.26		
Miller	7/8/91	2.88	−0.001	0.000	10.20	101.80	624	0.051	8.02		
Horns C.S.	7/8/91	0.01	0.000	0.031	23.70	592.40	1451	0.000	19.17		
Krueger	7/8/91	3.82	−0.004	−0.004	65.10	86.70	872	−0.004	12.04		
Zieber	7/8/91	3.23	−0.003	0.002	15.70	467.60	2393	−0.004	8.45		
Snyder	7/8/91	7.41	−0.004	−0.007	64.10	150.90	995	0.095	8.48		
Good	7/8/91	2.35	−0.003	−0.003	13.10	349.30	1000	−0.005	7.91		
Gross	7/8/91	0.11	0.002	0.002	8.50	461.60	1246	0.000	8.50		
Ringholz	7/8/91	4.02	−0.003	0.007	14.70	73.50	690	−0.003	9.85		
Koser	7/8/91	0.00	−0.005	0.059	16.90	1155.90	1058	0.008	8.16		
Meyer	7/8/91	0.02	−0.003	0.210	7.00	647.70	1388	−0.004	8.47		
Pocock	7/8/91	4.39	−0.004	−0.002	12.20	296.00	1033	−0.004	9.42		
Stone quarry	7/8/91	0.46	0.009	0.005	19.20	.644.10	1430	0.001	6.64		
Alt	7/8/91	0.01	−0.002	0.640	11.00	−9999.00	1579	−0.004	26.65		
Smith	7/8/91	4.10	−0.004	0.004	13.30	211.80	806	−0.005	7.20		

NAME	DATE	NO23	NO2	NH3	CL	SO4	COND	SRP	SIO2	TRISCR	ALASCR
Henney	8/12/91	0.93	0.000	−0.003	13.20	472.50	1257	0.006	6.88		
Miller	8/12/91	2.55	−0.001	−0.004	10.70	94.20	681	0.033	7.78	0.94	0.12
Horns C.S.	8/12/91	0.08	0.000	0.125	24.80	495.40	1524	0.004	18.17		
Krueger	8/12/91	2.37	0.000	0.008	63.70	84.60	838	0.004	11.64		
Zieber	8/12/91	2.93	−0.001	−0.002	16.30	480.30	1318	0.005	8.11		
Snyder	8/12/91	6.74	0.003	−0.003	64.50	114.20	975	0.096	8.38		
Good	8/12/91	2.30	−0.001	−0.001	13.00	249.40	1057	0.005	7.56		
Gross	8/12/91	0.19	0.009	−0.003	8.70	370.00	1222	0.004	8.15		
Ringholz	8/12/91	0.09	−0.001	0.002	4.70	912.00	740	0.011	9.31		

SENECA NPS WATER QUALITY DATA

Koser	8/12/91	0.05	0.000	0.092	17.50	912.30	1986	0.024	7.82		
Meyer	8/12/91	0.10	0.008	0.181	7.20	581.50	1340	0.005	8.19		
Pocock	8/12/91	4.18	0.000	−0.002	12.60	196.90	890	0.006	9.10		
Stone quarry	8/12/91	0.71	0.002	−0.003	21.30	542.60	1433	0.008	6.38		
Alt	8/12/91	0.07	−0.001	0.883	10.50	−999.00	3128	0.004	25.25		
Smith	8/12/91	3.99	−0.002	−0.002	13.50	152.90	785	0.005	6.92		
Williams	8/12/91	0.02	−0.001	0.038	49.70	61.00	891	0.008	8.29		

NAME	DATE	NO23	NO2	NH3	CL	SO4	COND	SRP	SIO2	TRISCR	ALASCR
Henny	9/1/91	0.55	−0.002	−0.001	13.40	651.50	1415	0.008	7.05		
Miller	9/1/91	2.03	0.004	0.051	11.00	151.80	711	0.033	7.98	1.06	0.82
Horns C.S.	9/1/91	0.14	−0.003	−0.002	24.30	569.40	1531	0.010	19.42		
Krueger	9/1/91	1.61	−0.001	−0.004	53.10	87.50	809	0.005	11.47		
Zieber	9/1/91	2.39	−0.002	−0.005	16.10	513.80	1314	0.005	8.30		
Snyder	9/1/91	5.75	0.012	−0.003	62.80	151.30	994	0.109	8.89		
Good	9/1/91	2.08	−0.002	−0.005	13.00	381.20	1049	0.004	7.81		
Gross	9/1/91	0.26	0.002	−0.004	8.00	350.70	1141	0.003	8.30		
Smith	9/1/91	4.31	−0.003	−0.004	13.10	209.80	785	0.007	6.96		
Koser	9/1/91	0.06	−0.003	0.096	17.50	1175.70	2017	0.023	7.98		
Meyer	9/1/91	0.06	−0.002	0.203	6.80	625.90	1351	0.004	8.01		
Pocock	9/1/91	3.66	−0.002	−0.004	12.20	354.70	1114	0.005	9.11		
Stone quarry	9/1/91	0.87	0.001	−0.007	23.90	674.10	1442	0.006	6.54		
Alt	9/1/91	0.07	−0.002	0.811	10.20	−9999.00	3134	0.007	25.40		
Williams	9/1/91	0.19	−0.002	0.063	48.00	126.30	904	0.004	8.73		

NAME	DATE	NO23	NO2	NH3	CL	SO4	COND	SRP	SIO2	TRISCR	ALASCR
Henney	10/1/91	0.21	−0.005	−0.012	14.20	794.70	1664	0.006	6.97		
Miller	10/1/91	1.85	−0.004	−0.012	9.90	129.80	643	0.039	8.07	1.03	0.14
Horns C.S.	10/1/91	0.16	−0.006	−0.009	25.30	527.30	1526	0.007	20.66		
Krueger	10/1/91	1.32	−0.006	−0.011	63.80	90.50	826	0.004	11.48		
Zieber	10/1/91	1.92	−0.006	−0.002	15.40	561.10	1385	0.002	8.09		
Snyder	10/1/91	5.54	0.009	−0.011	63.60	145.10	1008	0.103	8.77		
Good	10/1/91	1.97	−0.006	0.006	12.60	392.90	1103	0.003	7.74		
Gross	10/1/91	0.29	−0.006	−0.014	6.20	301.80	954	0.002	8.22		
Smith	10/1/91	2.15	−0.004	−0.011	12.90	239.00	830	0.002	6.75		
Koser	10/1/91	0.10	−0.005	0.070	17.50	1144.00	2105	0.008	7.94		
Meyer	10/1/91	0.09	−0.005	0.201	6.60	642.20	1415	0.003	8.21		
Pocock	10/1/91	2.78	−0.005	−0.006	11.60	401.80	1136	0.002	8.94		
Stone quarry	10/1/91	1.60	−0.005	−0.013	27.00	631.00	1411	0.005	6.23		
Alt	10/1/91	0.10	−0.001	0.749	10.40	−9999.00	3188	0.005	24.76		
Williams	10/1/91	0.09	−0.004	0.021	53.90	134.00	978	0.004	8.52		

SENECA NPS WATER QUALITY DATA

NAME	DATE	NO23	NO2	NH3	CL	SO4	COND	SRP	SIO2	TRISCR	ALASCR
Henney	11/9/91	0.18	0.180	0.013	15.20	991.80	1769	0.008	7.31		
Miller	11/9/91	1.26	0.018	0.026	10.10	148.10	710	0.035	8.04	1.01	0.02
Horns C.S.	11/9/91	0.15	0.013	0.004	25.40	553.70	1468	0.005	20.76		
Krueger	11/9/91	1.40	0.013	0.004	62.60	88.30	877	0.003	11.57		
Zieber	11/9/91	1.71	0.012	0.002	15.40	673.00	1448	0.014	8.42		
Good	11/9/91	1.85	0.013	0.059	12.50	409.90	1043	0.003	7.87		
Gross	11/9/91	0.33	0.014	0.008	6.40	340.30	979	0.003	8.35		
Smith	11/9/91	1.54	0.019	0.001	13.00	269.10	871	0.005	6.90		
Koser	11/9/91	0.04	0.013	0.126	17.50	−9999.00	2071	0.022	8.22		
Meyer	11/9/91	0.04	0.014	0.207	6.80	665.70	1398	0.003	8.15		
Pocock	11/9/91	2.69	0.012	0.000	11.60	428.70	1128	0.003	9.14		
Stone quarry	11/9/91	1.45	0.013	0.007	28.00	695.00	1468	0.006	6.39		
Alt	11/9/91	0.05	0.014	0.628	10.30	−9999.00	3033	0.006	20.83		
Williams	11/9/91	0.04	0.014	0.026	53.30	187.40	994	0.003	8.76		

NAME	DATE	NO23	NO2	NH3	CL	SO4	COND	SRP	SIO2	TRISCR	ALASCR
Henney	12/10/91	0.04	0.009	0.014	15.60	210.80	1837	0.015	7.09		
Miller	12/10/91	0.81	0.019	0.018	10.40	153.70	688	0.048	7.69	0.88	0.20
Horns C.S.	12/10/91	0.15	0.010	0.004	26.20	444.70	1441	0.006	20.05		
Krueger	12/10/91	1.67	0.011	0.004	66.80	152.30	933	0.006	11.40		
Zieber	12/10/91	1.44	0.010	0.001	15.60	559.70	1418	0.005	8.02		
Good	12/10/91	1.78	0.010	0.003	12.90	326.00	1025	0.004	7.67		
Gross	12/10/91	0.36	0.018	0.001	9.50	412.60	1219	0.003	8.24		
Smith	12/10/91	1.45	0.014	0.003	13.20	−7.80	−23	−0.002	−1.33		
Koser	12/10/91	0.02	0.009	0.132	18.10	182.80	2083	0.039	7.83		
Meyer	12/10/91	0.02	0.011	0.212	6.90	565.00	1345	0.005	8.26		
Pocock	12/10/91	2.58	0.009	0.006	11.90	411.60	1149	0.003	8.67		
Stone quarry	12/10/91	1.17	0.009	0.004	27.60	590.50	1430	0.010	6.15		
Alt	12/10/91	0.02	0.011	0.638	10.20	−9999.00	3060	0.007	22.99		
Williams	12/10/91	0.02	0.011	0.031	52.40	137.40	1011	0.002	8.32		
Ringholtz	12/10/91	0.10	0.009	0.011	6.10	102.80	695	0.012	9.18		

NAME	DATE	NO23	NO2	NH3	CL	SO4	COND	SRP	SIO2	TRISCR	ALASCR
Henney	1/1/92	0.04	0.001	0.015	15.70	1077.40	1937	0.001	7.39		
Krueger	1/1/92	0.93	0.000	0.003	66.40	67.80	923	0.004	11.55		
Zieber	1/1/92	1.20	0.000	0.002	15.70	625.40	1443	0.005	8.31		
Good	1/1/92	1.65	0.001	0.004	13.20	317.60	1008	0.006	7.89		
Gross	1/1/92	0.31	0.006	0.001	9.60	411.70	1220	0.002	8.48		
Smith	1/1/92	1.21	0.009	−0.001	13.30	216.30	870	0.006	6.88		

SENECA NPS WATER QUALITY DATA

Koser	1/1/92	0.02	0.001	0.139	18.50	1225.60	2198	0.031	8.36		
Meyer	1/1/92	0.02	0.001	0.224	7.20	614.50	1379	0.005	8.52		
Pocock	1/1/92	2.16	0.001	0.004	12.10	377.80	1140	0.003	9.18		
Stone quarry	1/1/92	0.67	0.000	−0.001	26.40	579.70	1460	0.008	6.45		
Williams	1/1/92	0.03	0.000	0.032	56.20	154.70	1014	0.004	8.49		
Ringholtz	1/1/92	0.10	0.000	0.002	6.60	74.80	685	0.011	9.60		

NAME	DATE	NO23	NO2	NH3	CL	SO4	COND	SRP	SIO2	TRISCR	ALASCR
Henney	2/20/92	0.03	0.010	0.004	16.80	1057.00	1132	0.049	−0.13		
Miller	2/20/92	11.98	1.098	0.080	9.40	55.40	392	0.042	7.38		
Horns C.S.	2/20/92	0.15	0.012	0.012	26.80	508.20	1367	0.005	21.92		
Krueger	2/20/92	1.61	0.015	0.011	47.70	74.40	638	0.004	10.83		
Zieber	2/20/92	0.89	0.015	0.006	15.80	646.70	1344	0.004	8.23		
Good	2/20/92	2.05	0.014	0.006	14.40	284.70	451	0.004	7.78		
Gross	2/20/92	0.16	0.028	0.014	8.90	597.10	1193	0.042	8.06		
Smith	2/20/92	5.40	0.015	0.013	17.30	200.40	699	0.005	7.99		
Koser	2/20/92	0.04	0.017	0.047	17.90	1127.70	2015	0.005	0.01		
Meyer	2/20/92	0.05	0.015	0.209	7.10	689.20	1386	0.006	8.06		
Pocock	2/20/92	1.14	0.013	0.010	12.10	404.10	1055	0.004	8.74		
Stone quarry	2/20/92	0.46	0.013	0.005	25.10	689.10	1428	0.008	6.26		
Alt	2/20/92	0.04	0.013	0.891	10.40	−9999.00	3073	0.004	24.69		
Ringholtz	2/20/92	0.08	0.015	0.006	6.60	86.00	533	0.005	9.37		

NAME	DATE	NO23	NO2	NH3	CL	SO4	COND	SRP	SIO2	TRISCR	ALASCR
Henney	3/13/92	0.11	0.034	−0.007	16.20	913.80	1760	0.013	6.97		
Miller	3/13/92	7.78	0.028	−0.004	9.80	68.60	527	0.049	7.39		
Horns C.S.	3/13/92	0.12	0.030	−0.001	15.70	990.60	1960	0.008	10.35		
Krueger	3/13/92	1.05	0.031	−0.004	45.70	80.70	792	0.007	10.55		
Zieber	3/13/92	0.78	0.033	−0.005	15.80	662.60	1473	0.007	7.87		
Good	3/13/92	2.13	0.034	−0.004	14.30	235.80	904	0.008	7.45		
Gross	3/13/92	0.10	0.041	0.011	9.90	575.60	1391	0.006	7.99		
Smith	3/13/92	7.23	0.033	−0.001	16.90	150.90	775	0.006	8.10		
Koser	3/13/92	0.09	0.039	0.071	18.10	1053.60	2013	0.024	7.69		
Meyer	3/13/92	0.08	0.031	0.187	7.40	639.70	1343	0.006	7.75		
Pocock	3/13/92	1.97	0.031	0.001	12.10	376.10	1124	0.006	8.62		
Stone quarry	3/13/92	0.74	0.031	−0.005	27.00	627.40	1374	0.012	6.17		
Alt	3/13/92	0.09	0.033	0.798	10.70	−9999.00	3168	0.005	23.15		
Ringholtz	3/13/92	0.09	0.031	−0.004	6.40	95.10	664	0.014	9.03		

NAME	DATE	NO23	NO2	NH3	CL	SO4	COND	SRP	SIO2	TRISCR	ALASCR
Warner	3/30/92	0.53	0.009	0.007	15.10	650.00	1469	0.005	7.87		

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Butz	3/30/92	1.38	0.009	0.010	13.30	78.50	599	0.004	8.10		
Stone Quarry	3/30/92	0.64	0.012	0.010	16.70	760.20	1490	0.008	5.05		
Smith	3/30/92	0.10	0.009	0.034	37.80	818.20	2104	0.004	15.68		
Zilch	3/30/92	0.57	0.009	0.014	8.00	210.30	955	0.004	8.13		
Decker	3/30/92	1.23	0.009	0.008	8.00	126.00	703	0.007	7.66		
Wollenslegel	3/30/92	7.82	0.009	0.007	15.20	65.50	657	0.008	7.66		
Hillman	3/30/92	0.10	0.009	0.093	3.50	163.90	908	0.005	11.26		
Myer	3/30/92	0.40	0.023	0.008	24.30	1144.80	2253	0.004	15.09		
Williamson	3/30/92	0.78	0.011	0.010	83.00	96.40	904	0.008	8.01		
Childrens Home	3/30/92	2.50	0.010	0.013	126.10	76.60	1140	0.003	7.54		
Decker	3/30/92	8.26	0.010	0.009	15.30	53.10	565	0.007	6.57		
Nearhood	3/30/92	2.56	0.012	0.010	24.70	107.80	563	0.019	7.54		
Kuhn	3/30/92	0.11	0.010	0.086	16.90	307.80	1160	0.007	14.89		
Cook	3/30/92	0.08	0.009	0.030	15.00	173.60	930	0.006	10.53		
Weasner	3/30/92	2.67	0.009	0.009	12.80	99.60	917	0.007	10.14		
Kimberlain	3/30/92	4.18	0.009	0.007	11.10	72.20	658	0.004	8.63		
Magyar	3/30/92	0.16	0.010	0.017	2.30	194.90	818	0.005	8.88		
Smith	3/30/92	6.10	0.012	0.011	24.10	72.60	757	0.004	7.78		
Rice	3/30/92	0.08	0.009	0.007	7.20	128.10	798	0.005	8.62		
Reau	3/30/92	0.10	0.008	0.020	9.30	104.80	801	0.004	9.17		
Hintz	3/30/92	1.46	0.009	0.008	19.80	257.50	1038	0.005	9.44		

NAME	DATE	NO23	NO2	NH3	CL	SO4	COND	SRP	SIO2	TRISCR	ALASCR
Steinmetz	4/6/92	8.70	0.001	0.006	21.60	210.00	1045	0.004	9.88		
Keesee	4/6/92	0.12	0.001	0.003	16.70	898.70	1793	0.006	7.35		
Norman	4/6/92	0.10	0.001	0.004	17.00	100.80	769	0.005	9.60		
Pit	4/6/92	0.77	0.001	0.007	15.30	596.60	1404	0.006	8.07		

NAME	DATE	NO23	NO2	NH3	CL	SO4	COND	SRP	SIO2	TRISCR	ALASCR
Henney	4/13/92	0.15	0.001	0.002	16.20	914.50	1799	0.007	7.13	0.05	0.08
Miller	4/13/92	8.23	0.012	0.031	9.30	75.00	578	0.035	7.50	0.86	0.06
Horns C.S.	4/13/92	0.03	0.001	0.011	16.20	991.20	1954	0.001	10.36	0.05	0.08
Krueger	4/13/92	2.61	0.002	0.004	68.80	91.30	920	−0.001	11.63	0.01	0.02
Zieber	4/13/92	0.64	0.001	0.004	16.10	722.70	1580	0.001	7.99	0.02	0.04
Good	4/13/92	1.81	0.001	0.006	14.30	290.60	1024	0.001	7.68	0.03	0.02
Gross	4/13/92	0.13	0.008	0.015	10.70	615.50	1440	0.000	8.15	0.01	0.03
Smith	4/13/92	6.28	0.001	0.004	16.40	110.40	826	0.002	8.09	0.02	0.02
Koser	4/13/92	0.34	0.188	0.014	18.10	1023.90	1954	0.010	7.60	0.20	0.21
Meyer	4/13/92	0.01	0.003	0.223	8.20	623.90	1375	0.001	8.20	0.07	0.02
Pocock	4/13/92	3.74	0.001	0.006	13.30	293.30	1035	−0.001	9.03	0.02	0.02

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Stone quarry	4/13/92	0.66	0.001	0.003	26.00	638.80	1445	0.003	6.31	0.01	0.05
Alt	4/13/92	0.01	0.002	0.696	12.10	114.40	3241	0.001	24.75	0.04	0.01
Ringholtz	4/13/92	0.08	0.002	0.006	6.80	96.40	685	0.006	9.33	0.01	0.02

NAME	DATE	NO23	NO2	NH3	CL	SO4	COND	SRP	SIO2	TRISCR	ALASCR
Henney	7/20/92	1.21	0.003	0.036	14.40	872.10	1679	0.000	7.24		
Horns C.S.	7/20/92	−0.01	−0.006	0.002	14.90	962.00	1990	0.002	9.99		
Krueger	7/20/92	2.97	0.006	0.073	47.30	77.70	846	0.006	11.13		
Zieber	7/20/92	0.89	0.007	0.000	16.10	646.90	1522	0.002	7.99		
Good	7/20/92	3.02	0.010	0.063	11.70	284.60	897	0.015	7.43		
Gross	7/20/92	0.02	0.006	0.129	10.10	593.70	1418	0.001	8.10		
Smith	7/20/92	8.38	−0.007	0.000	15.40	5.70	802	0.004	7.30		
Koser	7/20/92	0.37	0.018	0.001	17.00	947.20	1822	0.004	7.64		
Meyer	7/20/92	0.03	0.002	0.074	7.60	700.60	1431	0.000	8.14		
Pocock	7/20/92	3.73	0.003	0.095	14.00	381.60	1144	0.002	9.16		
Stone quarry	7/20/92	1.77	−0.006	0.003	30.10	668.90	1387	0.005	6.00		
Alt	7/20/92	−0.01	0.008	0.888	12.30	−9999.00	3289	0.007	26.03		
Ringholtz	7/20/92	0.05	−0.005	0.002	5.80	88.40	684	0.002	9.24		

NAME	DATE	NO23	NO2	NH3	CL	SO4	COND	SRP	SIO2	TRISCR	ALASCR
Henney	8/10/92	1.22	0.011	0.031	14.80	654.20	1652	0.005	7.30		
Horns C.S.	8/10/92	0.04	0.010	0.034	13.70	817.40	1968	0.003	9.84		
Krueger	8/10/92	0.14	0.003	0.033	9.30	72.40	626	0.003	10.00		
Zieber	8/10/92	1.57	0.009	0.029	15.50	521.00	1504	0.002	7.99		
Good	8/10/92	2.94	0.011	0.032	12.60	114.80	984	0.002	7.79		
Gross	8/10/92	0.02	0.015	0.033	10.50	387.40	1377	0.003	8.27		
Smith	8/10/92	8.06	0.011	0.032	12.50	−36.00	775	0.003	7.23		
Koser	8/10/92	0.21	0.083	0.033	16.30	828.20	1887	0.009	7.72		
Meyer	8/10/92	0.01	0.012	0.169	7.80	487.40	1402	0.004	8.38		
Pocock	8/10/92	3.89	0.011	0.033	13.60	176.90	1116	0.003	9.30		
Stone quarry	8/10/92	2.10	0.010	0.031	27.70	348.00	1266	0.005	5.66		
Alt	8/10/92	0.04	0.010	0.853	11.80	777.60	3034	0.003	28.04		
Ringholtz	8/10/92	4.30	0.010	0.032	14.40	60.50	682	0.005	9.74		
Snyder	8/10/92	6.82	0.016	0.032	60.00	−51.60	983	0.096	9.02		

NAME	DATE	NO23	NO2	NH3	CL	SO4	COND	SRP	SIO2	TRISCR	ALASCR
Henney	9/4/92	1.21	0.015	0.021	15.10	633.80	1584	0.003	7.16		
Horns C.S.	9/4/92	0.03	0.004	0.027	14.30	867.80	1960	0.006	10.05		
Krueger	9/4/92	3.12	0.004	0.024	53.50	82.00	860	0.002	10.80		
Zieber	9/4/92	1.85	0.004	0.025	15.80	529.60	1446	0.003	8.01		
Good	9/4/92	2.78	0.004	0.025	13.70	196.40	983	0.006	7.63		

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Gross	9/4/92	0.05	0.005	0.024	10.10	467.40	1356	0.003	8.04		
Smith	9/4/92	6.47	0.004	0.025	13.00	71.20	790	0.002	7.09		
Koser	9/4/92	0.04	0.004	0.033	17.20	939.30	1960	0.012	7.70		
Meyer	9/4/92	0.01	0.005	0.169	8.10	529.30	1406	0.004	8.19		
Pocock	9/4/92	3.87	0.004	0.025	13.80	256.00	1115	0.005	9.07		
Stone quarry	9/4/92	2.00	0.007	0.026	28.80	535.10	1350	0.007	5.65		
Alt	9/4/92	0.03	0.019	0.830	13.50	−9999.00	3230	0.010	25.60		
Ringholtz	9/4/92	4.06	0.003	0.023	14.20	72.30	699	0.002	9.40		
Snyder	9/4/92	6.55	0.014	0.028	63.30	50.40	979	0.082	8.95		
Williams	9/4/92	1.08	0.014	0.026	56.80	112.50	1048	0.002	8.66		

NAME	DATE	NO23	NO2	NH3	CL	SO4	COND	SRP	SIO2	TRISCR	ALASCR
Henney	10/8/92	1.49	−0.001	0.023	14.60	786.80	1468	−0.002	7.26		
Horns C.S.	10/8/92	0.07	−0.001	0.031	13.70	1029.40	1864	−0.004	10.48		
Krueger	10/8/92	1.80	−0.003	0.023	37.80	163.00	807	−0.001	10.72		
Zieber	10/8/92	2.48	−0.003	0.029	15.70	597.30	1417	−0.002	8.01		
Good	10/8/92	3.34	−0.001	0.025	12.60	332.00	830	−0.002	7.74		
Gross	10/8/92	0.10	0.002	0.019	10.70	585.50	1218	0.000	8.37		
Smith	10/8/92	6.96	−0.002	0.021	12.80	226.20	691	0.002	7.26		
Koser	10/8/92	0.13	0.032	0.027	15.90	983.90	1844	0.009	7.53		
Meyer	10/8/92	0.09	0.000	0.206	8.70	649.90	1379	−0.001	8.19		
Pocock	10/8/92	4.21	−0.004	0.022	13.80	96.80	945	−0.004	6.33		
Stone quarry	10/8/92	1.84	−0.003	0.019	26.60	641.70	1374	−0.002	5.96		
Alt	10/8/92	0.09	−0.002	0.857	12.40	−9999.00	3147	−0.001	22.70		
Ringholtz	10/8/92	3.51	−0.002	0.043	11.50	93.20	629	0.001	9.64		
Snyder	10/8/92	6.91	0.032	0.087	63.20	243.50	1008	0.152	9.26		
Williams	10/8/92	0.38	0.009	0.032	59.20	177.50	928	−0.003	8.63		

NAME	DATE	NO23	NO2	NH3	CL	SO4	COND	SRP	SIO2	TRISCR	ALASCR
Henney	11/10/92	1.45	−0.001	0.007	14.20	601.10	1482	0.007	13.79		
Horns C.S.	11/10/92	0.01	−0.001	0.008	13.90	904.70	1890	0.002	19.10		
Krueger	11/10/92	4.01	0.002	0.006	60.40	75.30	896	0.005	21.49		
Zieber	11/10/92	2.85	0.000	0.006	16.00	440.40	1369	0.004	15.69		
Good	11/10/92	2.89	−0.001	0.005	13.60	231.50	983	0.003	14.76		
Gross	11/10/92	0.02	0.001	0.008	9.00	476.40	1334	0.002	15.43		
Smith	11/10/92	5.70	0.000	0.005	12.50	126.50	764	0.004	13.58		
Koser	11/10/92	0.00	0.000	0.056	15.90	937.50	1897	0.021	14.81		
Meyer	11/10/92	1.15	−0.001	0.006	7.40	566.00	1499	0.001	19.25		
Pocock	11/10/92	4.08	0.000	0.007	13.40	269.00	1113	0.002	17.33		
Stone quarry	11/10/92	1.14	0.000	0.004	24.00	556.50	1392	0.006	11.61		
Alt	11/10/92	0.02	−0.001	0.734	11.20	−9999.00	3162	0.004	52.50		

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Ringholtz	11/10/92	5.54	0.000	0.007	17.00	62.30	706	0.003	18.26		
Williams	11/10/92	0.95	0.005	0.009	57.30	119.30	1056	0.002	16.79		

NAME	DATE	NO23	NO2	NH3	CL	SO4	COND	SRP	SIO2	TRISCR	ALASCR
Henney	12/2/92	1.76	-0.004	0.006	13.00	603.20	1500	0.006	7.00		
Horns C.S.	12/2/92	0.00	-0.002	0.023	13.00	970.40	2126	0.007	9.59		
Krueger	12/2/92	3.44	-0.005	0.008	63.10	80.50	965	0.001	11.48		
Zieber	12/2/92	3.32	-0.005	0.007	15.50	524.70	1459	0.002	8.07		
Good	12/2/92	3.17	-0.001	0.013	10.80	189.40	787	0.002	6.84		
Gross	12/2/92	-0.02	-0.004	0.016	9.40	519.40	1405	0.000	7.98		
Smith	12/2/92	7.09	-0.004	0.009	13.20	165.70	798	0.007	7.02		
Koser	12/2/92	0.48	0.019	0.008	14.50	845.00	1860	0.011	7.40		
Meyers	12/2/92	-0.01	-0.001	0.221	8.00	633.10	1489	0.007	8.18		
Pocock	12/2/92	4.25	-0.005	0.006	11.20	339.80	1187	0.000	8.95		
Stone quarry	12/2/92	2.98	-0.004	0.076	24.40	452.20	1173	0.007	5.71		
Alt	12/2/92	0.01	0.000	0.782	12.00	-9999.00	3566	0.024	18.97		
Ringholtz	12/2/92	0.04	-0.004	0.007	7.70	115.20	743	0.004	9.17		
Williams	12/2/92	0.86	0.012	0.021	44.20	157.20	1023	0.001	8.10		

NAME	DATE	NO23	NO2	NH3	CL	SO4	COND	SRP	SIO2	TRISCR	ALASCR
Henney	1/5/93	1.52	-0.001	0.024	12.40	570.30	1415	0.003	6.86		
Horns C.S.	1/5/93	-0.01	-0.002	0.030	12.70	930.70	987	0.003	9.22		
Krueger	1/5/93	5.17	-0.001	0.025	70.40	71.40	944	0.001	11.73		
Zieber	1/5/93	6.11	-0.001	0.026	14.90	325.40	1186	0.003	7.96		
Good	1/5/93	3.32	-0.001	0.025	10.70	167.50	826	0.002	7.15		
Gross	1/5/93	0.00	0.000	0.027	9.00	460.20	1309	-0.001	7.80		
Smith	1/5/93	6.36	0.002	0.030	10.50	83.20	616	0.009	6.73		
Koser	1/5/93	0.80	0.005	0.028	13.50	781.10	1606	0.005	7.09		
Meyers	1/5/93	0.00	-0.002	0.213	7.50	591.90	1391	0.001	7.95		
Pocock	1/5/93	1.03	-0.015	0.033	12.50	352.60	1198	0.004	8.40		
Stone quarry	1/5/93	3.07	0.016	0.051	22.10	117.50	665	0.020	5.39		
Alt	1/5/93	-0.01	0.001	0.806	12.00	-9999.00	1669	0.002	24.27		
Williams	1/5/93	0.20	0.011	0.026	43.00	88.00	939	0.000	7.68		

NAME	DATE	NO23	NO2	NH3	CL	SO4	COND	SRP	SIO2	TRISCR	ALASCR
Henney	2/8/93	1.02	0.019	0.093	14.70	742.90	1547	0.007	6.93		
Horns C.S.	2/8/93	0.03	0.018	0.092	13.40	924.80	1812	0.001	9.46		
Krueger	2/8/93	3.52	0.019	0.091	65.20	75.70	919	0.001	11.26		
Zieber	2/8/93	4.26	0.012	0.090	15.80	456.10	1262	0.002	8.11		
Good	2/8/93	3.65	0.019	0.091	11.50	185.40	790	0.000	7.04		
Gross	2/8/93	0.02	0.021	0.091	10.20	477.70	1248	0.000	7.89		

SENECA NPS WATER QUALITY DATA

Smith	2/8/93	5.59	0.018	0.086	12.50	145.30	718	0.007	6.91		
Koser	2/8/93	0.37	0.094	0.092	15.80	867.20	1703	0.012	7.34		
Meyer	2/8/93	0.00	0.019	0.103	7.80	593.60	1343	0.005	8.10		
Pocock	2/8/93	4.55	0.014	0.092	14.00	338.60	1122	0.000	8.70		
Stone quarry	2/8/93	2.54	0.018	0.084	15.90	513.80	1158	0.007	5.70		
Alt	2/8/93	0.16	0.019	0.363	11.60	-9999.00	3136	0.008	20.93		
Williams	2/8/93	0.34	0.029	0.091	53.60	127.10	989	-0.001	8.07		
Miller	2/8/93	6.12	0.025	0.103	8.40	70.50	600	0.056	8.01		
Ringholtz	2/8/93	2.15	0.018	0.090	9.10	78.50	714	0.003	9.18		
NAME	DATE	NO23	NO2	NH3	CL	SO4	COND	SRP	SIO2	TRISCR	ALASCR
Henney	3/2/93	0.64	0.014	0.050	15.50	812.70	1720	0.008	6.98		
Horns C.S.	3/2/93	0.02	0.016	0.056	14.70	886.00	1938	0.007	9.34		
Krueger	3/2/93	3.53	0.014	0.051	69.10	86.30	945	0.000	10.95		
Zieber	3/2/93	4.67	0.013	0.051	17.00	405.80	1248	0.003	7.95		
Good	3/2/93	3.58	0.013	0.050	12.50	209.00	845	0.001	7.15		
Gross	3/2/93	0.05	0.017	0.051	10.00	466.40	1277	-0.002	7.81		
Smith	3/2/93	4.95	0.014	0.051	12.30	144.70	662	0.006	6.71		
Koser	3/2/93	0.02	0.019	0.048	16.10	916.40	1896	0.012	7.39		
Meyer	3/2/93	0.06	0.016	0.214	8.80	590.60	1368	0.004	7.88		
Pocock	3/2/93	4.57	0.014	0.049	14.30	315.00	1127	0.000	8.63		
Stone quarry	3/2/93	0.65	0.013	0.048	16.70	579.10	1343	0.005	6.12		
Alt	3/2/93	0.07	0.017	0.537	12.80	-9999.00	3033	0.001	21.83		
Williams	3/2/93	0.20	0.200	0.500	66.80	135.70	1038	0.000	7.87		
Miller	3/2/93	5.35	0.036	0.082	13.30	144.20	637	0.055	7.68		
Ringholtz	3/2/93	6.59	0.014	0.052	18.80	64.10	713	0.001	9.11		
NAME	DATE	NO23	NO2	NH3	CL	SO4	COND	SRP	SIO2	TRISCR	ALASCR
Henney	4/7/93	1.88	0.020	0.061	11.60	553.30	1238	0.001	6.75		
Horns C.S.	4/7/93	0.08	0.019	0.065	13.80	966.90	1897	0.003	9.37		
Krueger	4/7/93	14.28	0.023	0.065	134.50	41.60	1122	-0.001	12.88		
Zieber	4/7/93	4.61	0.021	0.064	15.90	432.20	1230	0.000	8.14		
Good	4/7/93	3.37	0.021	0.065	9.90	209.60	734	0.000	6.86		
Gross	4/7/93	0.04	0.020	0.065	9.20	454.50	1227	-0.001	7.86		
Smith	4/7/93	5.15	0.023	0.064	12.00	141.70	673	0.000	6.91		
Koser	4/7/93	0.76	0.020	0.063	13.10	808.10	1591	0.005	7.13		
Meyers	4/7/93	0.04	0.019	0.100	7.80	629.10	1350	0.002	7.99		
Pocock	4/7/93	4.95	0.021	0.066	13.00	341.20	1084	-0.002	8.79		
Stone quarry	4/7/93	6.54	0.068	0.064	21.50	431.80	1072	0.001	5.65		
Alt	4/7/93	0.07	0.019	0.362	10.90	1760.20	3272	-0.001	17.12		
Williams	4/7/93	1.57	0.035	0.065	32.40	167.60	859	-0.001	7.66		

SENECA NPS WATER QUALITY DATA

Smith	2/8/93	5.59	0.018	0.086	12.50	145.30	718	0.007	6.91		
Koser	2/8/93	0.37	0.094	0.092	15.80	867.20	1703	0.012	7.34		
Meyer	2/8/93	0.00	0.019	0.103	7.80	593.60	1343	0.005	8.10		
Pocock	2/8/93	4.55	0.014	0.092	14.00	338.60	1122	0.000	8.70		
Stone quarry	2/8/93	2.54	0.018	0.084	15.90	513.80	1158	0.007	5.70		
Alt	2/8/93	0.16	0.019	0.363	11.60	−9999.00	3136	0.008	20.93		
Williams	2/8/93	0.34	0.029	0.091	53.60	127.10	989	−0.001	8.07		
Miller	2/8/93	6.12	0.025	0.103	8.40	70.50	600	0.056	8.01		
Ringholtz	2/8/93	2.15	0.018	0.090	9.10	78.50	714	0.003	9.18		

NAME	DATE	NO23	NO2	NH3	CL	SO4	COND	SRP	SIO2	TRISCR	ALASCR
Henney	3/2/93	0.64	0.014	0.050	15.50	812.70	1720	0.008	6.98		
Horns C.S.	3/2/93	0.02	0.016	0.056	14.70	886.00	1938	0.007	9.34		
Krueger	3/2/93	3.53	0.014	0.051	69.10	86.30	945	0.000	10.95		
Zieber	3/2/93	4.67	0.013	0.051	17.00	405.80	1248	0.003	7.95		
Good	3/2/93	3.58	0.013	0.050	12.50	209.00	845	0.001	7.15		
Gross	3/2/93	0.05	0.017	0.051	10.00	466.40	1277	−0.002	7.81		
Smith	3/2/93	4.95	0.014	0.051	12.30	144.70	662	0.006	6.71		
Koser	3/2/93	0.02	0.019	0.048	16.10	916.40	1896	0.012	7.39		
Meyer	3/2/93	0.06	0.016	0.214	8.80	590.60	1368	0.004	7.88		
Pocock	3/2/93	4.57	0.014	0.049	14.30	315.00	1127	0.000	8.63		
Stone quarry	3/2/93	0.65	0.013	0.048	16.70	579.10	1343	0.005	6.12		
Alt	3/2/93	0.07	0.017	0.537	12.80	−9999.00	3033	0.001	21.83		
Williams	3/2/93	0.20	0.200	0.500	66.80	135.70	1038	0.000	7.87		
Miller	3/2/93	5.35	0.036	0.082	13.30	144.20	637	0.055	7.68		
Ringholtz	3/2/93	6.59	0.014	0.052	18.80	64.10	713	0.001	9.11		

NAME	DATE	NO23	NO2	NH3	CL	SO4	COND	SRP	SIO2	TRISCR	ALASCR
Henney	4/7/93	1.88	0.020	0.061	11.60	553.30	1238	0.001	6.75		
Horns C.S.	4/7/93	0.08	0.019	0.065	13.80	966.90	1897	0.003	9.37		
Krueger	4/7/93	14.28	0.023	0.065	134.50	41.60	1122	−0.001	12.88		
Zieber	4/7/93	4.61	0.021	0.064	15.90	432.20	1230	0.000	8.14		
Good	4/7/93	3.37	0.021	0.065	9.90	209.60	734	0.000	6.86		
Gross	4/7/93	0.04	0.020	0.065	9.20	454.50	1227	−0.001	7.86		
Smith	4/7/93	5.15	0.023	0.064	12.00	141.70	673	0.000	6.91		
Koser	4/7/93	0.76	0.020	0.063	13.10	808.10	1591	0.005	7.13		
Meyers	4/7/93	0.04	0.019	0.100	7.80	629.10	1350	0.002	7.99		
Pocock	4/7/93	4.95	0.021	0.066	13.00	341.20	1084	−0.002	8.79		
Stone quarry	4/7/93	6.54	0.068	0.064	21.50	431.80	1072	0.001	5.65		
Alt	4/7/93	0.07	0.019	0.362	10.90	1760.20	3272	−0.001	17.12		
Williams	4/7/93	1.57	0.035	0.065	32.40	167.60	859	−0.001	7.66		

SENECA NPS WATER QUALITY DATA

Miller	4/7/93	9.23	0.023	0.066	19.80	134.20	761	0.028	7.94		
Kreglow	4/7/93	4.37	0.016	0.065	13.20	71.00	699	−0.001	9.14		

NAME	DATE	NO23	NO2	NH3	CL	SO4	COND	SRP	SIO2	TRISCR	ALASCR
Decker	4/22/93	7.44	−0.007	0.053	13.90	54.70	612	−0.001	6.84		
Myer	4/22/93	0.03	0.002	0.054	18.60	873.00	1241	0.001	15.16		
Pocock	4/22/93	5.21	0.002	0.051	13.40	423.50	1077	0.002	8.72		
Weasner	4/22/93	2.63	0.002	0.054	16.50	171.20	1043	0.008	10.29		
Norman	4/22/93	3.26	0.003	0.052	38.80	88.80	820	0.001	9.08		
Good	4/22/93	3.31	0.002	0.051	9.60	184.40	686	0.001	6.49		
Krueger	4/22/93	11.77	0.003	0.052	146.20	47.40	1164	−0.001	12.64		
Henney	4/22/93	0.95	0.002	0.052	13.10	575.60	1487	0.005	6.82		
Ringholz	4/22/93	3.61	0.002	0.051	12.20	80.60	697	0.002	9.02		
Williamson	4/22/93	2.99	0.004	0.081	24.50	268.20	1045	−0.002	9.57		
Warner	4/22/93	4.62	0.002	0.052	15.00	129.90	1306	0.002	7.66		
Childrens Home	4/22/93	6.27	0.002	0.053	102.50	101.10	992	0.001	7.43		
Hillman	4/22/93	0.00	0.002	0.123	3.30	142.10	872	0.001	10.49		
Horns C.S.	4/22/93	0.03	0.002	0.053	13.40	551.70	1933	0.001	9.41		
Wollenslegel	4/22/93	6.70	0.002	0.054	11.00	52.90	588	0.008	7.76		
Stone Quarry	4/22/93	3.31	0.002	0.053	17.00	620.20	1194	0.008	6.21		
Cook	4/22/93	13.62	1.102	0.079	11.00	53.90	685	0.004	7.73		
Decker	4/22/93	3.84	0.004	0.053	10.60	78.70	624	0.003	7.57		
Zilch	4/22/93	0.55	−0.010	0.049	7.60	372.90	1042	0.006	8.12		
Rice	4/22/93	0.01	0.002	0.052	8.20	140.10	733	0.002	8.80		
Butz	4/22/93	15.27	0.002	0.052	16.10	59.90	752	0.000	8.40		
Kuhn	4/22/93	0.04	0.003	0.087	22.50	256.20	1180	−0.001	12.38		
Williams	4/22/93	1.63	0.018	0.054	34.40	154.20	874	0.001	7.66		
Smith	4/22/93	5.11	0.003	0.052	11.80	181.20	685	0.008	6.68		
Gross	4/22/93	0.03	0.003	0.051	9.20	637.40	1217	0.000	7.83		
Reau	4/22/93	0.17	0.004	0.086	31.90	223.90	1194	0.008	9.70		
Zieber	4/22/93	4.87	0.004	0.053	16.70	593.50	1220	0.002	8.11		
Koser	4/22/93	0.56	0.027	0.053	14.30	1180.70	1679	0.007	7.22		
Hintz	4/22/93	6.79	0.002	0.055	28.50	200.20	936	0.001	9.10		
Alt	4/22/93	−0.05	0.002	0.501	11.20	−9999.00	1648	0.001	22.27		
Meyer	4/22/93	0.04	0.002	0.088	7.50	912.80	1349	0.001	7.84		
Smith	4/22/93	14.20	0.002	0.082	20.60	72.30	874	0.003	8.03		
Miller	4/22/93	6.71	0.009	0.056	10.30	181.20	562	0.012	7.26		
Bickel	4/22/93	8.47	0.004	0.052	33.70	48.40	667	0.020	7.57		
Walters	4/22/93	6.24	0.004	0.047	14.70	501.80	1102	0.001	7.59		
Artino−Kimberlain	4/22/93	8.07	0.003	0.053	17.70	50.80	675	0.000	8.09		
Holmer	4/22/93	2.87	0.002	0.053	79.90	791.60	1494	0.000	9.48		

SENECA NPS WATER QUALITY DATA

NAME	DATE	NO23	NO2	NH3	CL	SO4	COND	SRP	SIO2	TRISCR	ALASCR
Henney	4/30/93	0.81	0.198	0.109	13.30	827.80	1625	0.001	7.13		
Horns C.S.	4/30/93	−0.18	−0.153	0.119	13.00	988.00	1988	0.007	9.45		
Krueger	4/30/93	10.94	0.198	0.110	120.20	49.00	946	0.005	12.82		
Zieber	4/30/93	5.11	0.202	0.122	15.70	504.70	1107	0.001	8.31		
Good	4/30/93	3.74	0.200	0.115	10.30	284.00	669	0.001	6.85		
Gross	4/30/93	−0.06	0.199	0.116	9.20	545.70	1023	0.001	8.04		
Smith	4/30/93	4.89	0.183	0.140	11.30	257.70	635	0.005	6.79		
Koser	4/30/93	0.41	0.247	0.130	13.90	914.30	1768	0.004	7.44		
Meyer	4/30/93	−0.06	0.202	0.112	7.40	690.60	1340	0.002	8.33		
Pocock	4/30/93	5.80	0.203	0.104	13.70	412.30	930	0.003	9.08		
Stone quarry	4/30/93	8.35	0.245	0.642	22.60	565.70	1181	0.001	6.20		
Alt	4/30/93	0.04	0.197	0.108	10.60	−9999.00	2837	0.002	18.75		
Schneider	4/30/93	10.03	0.200	0.116	51.30	272.50	890	0.081	7.08		
Ringholtz	4/30/93	5.47	0.182	0.114	14.90	78.90	625	0.003	9.33		

NAME	DATE	NO23	NO2	NH3	CL	SO4	COND	SRP	SIO2	TRISCR	ALASCR
Henney	6/14/93	1.15	0.010	0.162	11.90	642.30	1312				
Horns C.S.	6/14/93	0.00	0.011	0.161	14.30	976.80	1887				
Krueger	6/14/93	3.61	0.010	0.157	63.70	92.80	979				
Zieber	6/14/93	4.94	0.011	0.165	16.30	455.80	1163				
Good	6/14/93	3.41	0.011	0.162	12.00	238.30	847				
Gross	6/14/93	0.06	0.013	0.154	9.30	505.90	1232				
Koser	6/14/93	−0.01	0.010	0.161	14.60	1007.50	1789				
Meyer	6/14/93	0.02	0.011	0.166	7.70	700.70	1360				
Pocock	6/14/93	6.06	0.011	0.166	14.00	342.60	1080				
Alt	6/14/93	0.02	0.018	0.548	11.10	−9999.00	3203				
Ringholtz	6/14/93	6.42	0.011	0.162	17.80	67.70	696				

NAME	DATE	NO23	NO2	NH3	CL	SO4	COND	SRP	SIO2	TRISCR	ALASCR
Henney	7/1/93	0.71	0.006	0.009	14.30	723.10	1821	0.006	6.61	0.03	0.11
Horns C.S.	7/1/93	0.04	0.007	0.015	14.30	671.10	2162	0.001	9.17	0.03	0.11
Krueger	7/1/93	4.81	0.006	0.013	65.10	76.30	1032	0.002	10.57	0.01	0.04
Zieber	7/1/93	4.84	0.007	0.021	17.60	377.00	1350	0.001	7.77	0.02	0.03
Good	7/1/93	3.25	0.008	0.012	12.30	199.90	967	0.009	6.92	0.06	1.31
Gross	7/1/93	0.10	0.010	0.015	9.50	440.20	1426	0.001	7.55	0.01	0.03
Koser	7/1/93	0.05	0.005	0.012	15.20	885.90	2040	0.007	7.01	0.28	0.30
Meyer	7/1/93	4.64	0.005	0.009	42.60	418.00	1300	0.009	4.98	0.08	0.31
Pocock	7/1/93	6.91	0.007	0.014	14.00	259.10	1178	0.001	8.26	0.01	0.02
Alt	7/1/93	0.03	0.007	0.740	11.20	−9999.00	3935	0.008	22.34	0.01	0.02

SENECA NPS WATER QUALITY DATA

Ringholtz	7/1/93	6.46	0.005	0.010	18.60	67.60	860	0.004	9.02	0.02	0.03
Smith	7/1/93	3.75	0.006	0.014	11.50	131.00	761	0.003	6.32	0.08	0.09
Stone Quarry	7/1/93	0.03	0.006	0.025	7.90	628.60	1960	0.006	7.74	0.15	0.06
Schneider	7/1/93	7.15	0.007	0.012	59.70	132.90	1106	0.058	7.17	0.02	0.06

APPENDIX C

WASTEWATER MANAGEMENT COMMITTEE SURVEYS AND FORMS

- Community Sewage Facilities Survey with results
- Response letter sent to survey participants
- Septic System Cost Share Form
- Water Saver Kit contents

COMMUNITY SEWAGE FACILITIES SURVEY

Thank you for taking a few minutes for this interview.

Many rural areas in Ohio are growing, and they face the problem of providing adequate sewage service to protect the public health and the environment. Information about the existing sewage treatment facilities and home and family needs is important for making the right choices in any community. The sewage facilities study committee is asking your help in meeting these information needs.

This questionnaire is designed to gather important information about your sewage facility requirements. All of your responses will be kept completely confidential, your name will not be placed on the questionnaire. You are free to not answer any particular question and your cooperation is voluntary. By our gathering this information about the homes, family needs, and current sewage facilities ourselves, we can save the community a great deal of money in planning and decision making.

The results of this survey will be used by the sewage facilities study committee to avoid making costly mistakes in meeting our goal to protect your health and the environment.

This survey should take about 10 minutes to complete. Do you have any questions before we get started?

The homes in this community vary in size and age.

Q-1 When was your home built?

1. Before 1950
2. 1950 - 1960
3. 1961 - 1970
4. 1971 - 1980
5. Since 1980
6. not sure

Q-2 Home sizes in a community are measured by the number of bedrooms they contain. What is the size of your home right now?

1. no bedrooms
2. one-bedroom
3. two-bedrooms
4. three-bedrooms
5. four-bedrooms
6. five or more bedrooms

Q-3 Have any rooms been converted to bedrooms or have bedrooms been added to the house since it was built?

1. not sure
2. no
3. yes ____

How many bedrooms have been added or converted?

1. one bedroom
2. two bedrooms
3. three or more bedrooms

Q-4 The homes in this community are also built on different size lots. Do you know the size of this lot?

1. no
2. not sure
3. yes (fill in only one set of dimensions)

1. ____ft. by ____ft.
2. ________square ft.
3. _______acres
4. Other measurements_______________
5. __________paces by _________paces.

Q-5 How many people live in your home year round?

____

Q-6 Sometimes decisions to provide sewage services cost money. Because the sewage facilities study committee does not want to impose a hardship on anyone, we are collecting information on household income levels. What was the combined net income for 1991 for this household for the past 3 years? (3 X 5 card)

Q-7 Some home septic systems don't have sink or washing machine water (grey water) draining into the septic tank. Does yours?

1. yes
2. no

If no, where does this water drain?

Q-8 All of the homes in our community have a septic system of some sort to treat their wastewater, but since they are usually buried in the yard, not many people know what kind of system they have. Do you know if the sewage from your home is discharged to a tank?

1. no
2. yes
3. not sure -- DO YOU HAVE ANY IDEA?

What type of tank is it?

1. septic tank
2. aerobic tank
3. other________________________

Where does the tank discharge?

1. leach field in the yard
2. road ditch
3. farm drain tile
4. stream
5. ravine
6. other____________________

Q-9 Do you know where the septic system is located in your lot?

1. no
2. yes
3. not sure - DO YOU KNOW WHERE IT MIGHT BE?

1. front yard
2. back yard
3. side of house

Q-10 Over a lifetime of a home, a septic tank sometimes needs to be pumped out. About how often have you had your septic tank pumped?

1. not sure
2. once since lived in the house
3. more than once since lived in the house
4. not at all

Q-11 Wet spots are common occurrences in yards with on-site septic systems. In what seasons do you have wet spots in your yard? (circle all that apply)

1. in the spring
2. in the summer
3. in the fall
4. in the winter
5. not at all

Q-12 Septic systems in our community have been installed for years. When was the system for your house first installed?

1. Before 1950
2. 1950 - 1960
3. 1961 - 1970
4. 1971 - 1980
5. since 1980
6. not sure

Has your system been repaired or modified since it was installed?

1. not sure
2. no
3. yes

When was this work done?

1. Before 1950
2. 1950 - 1960
3. 1961 - 1970
4. 1971 - 1980
5. since 1980
6. not sure

Q-13 Do you have a usable outhouse? Yes No

Q-14 Do you Know how a septic system works?

Yes No

Q-15 The interview is almost over. Here are a few statements about community issues related to sewage treatment. Please indicate if you agree, disagree, or have no feeling about each statement.

Circle the Response

	No feeling	agree	disagree
Sewage odors are offensive in this community.	NF	A	D
Septic systems should be permitted in this community.	NF	A	D
It is acceptable to discharge sewage to streams and sinkholes.	NF	A	D
I favor the construction or upgrades of my septic system, if needed.	NF	A	D
I am willing to help pay for an upgraded or new septic system if needed.	NF	A	D

This completes the interview. Thank you for your time. The results will be compiled and sent to you.

Dear participant:

Thank you very much for your interest in the community sewage facilities survey of Thompson Township. Enclosed is the results of the survey. IN ORDER TO SAVE SPACE WE INCLUDED ONLY THE MAJOR AND MINOR PERCENTAGES! If you have any questions feel free to call Seneca SWCD at 447-7073.

50% or 238 of the homes were surveyed in the township.
46 % of the homes were built before 1950.
21 % were built between the years of 1971-1980.
11.2 % were built since 1980.

51 % of the homes have 3 bedrooms.
8 % have 5 or more bedrooms.
25 % have 4 bedrooms.

25 % of the homes are built on less than 1 acre lots.
27 % are on 1 acre lots.
19 % are on greater than 4 acres.

34% of the households have net incomes greater than $30,000.
28% have incomes between $20,000 - $30,000.
10% have incomes less than $10,000.

87% of the residents knew that they have a septic system.
92% use a septic tank.
7% have an aerobic tank.
84% have a leachfield.
3% use the road ditch after the tank
11% use a farm drain tile after the tank

21% have had their septic tank pumped once.
56% have had their tank pumped more than once.
18% have never had their tank pumped.

79% have never experienced wet spots in their yards.
15% have wet spots in the spring.

11% had their septic system installed before 1950.
18% from 1950 - 1960
17% from 1961 - 1970
26% from 1971 - 1980
10% since 1980

6% have a usable outhouse.
89% said they know how a septic system works.

Sewage odors are offensive near their community.	28% agree	63% disagree
Septic systems should be allowed in the community.	92% agree	4% disagree

It"s acceptable to dicharge sewage into streams or sinkholes. 3% agree 95%disagree

I favor the upgrade of my septic system if needed. 85% agree 7% disagree

I am willing to help pay for this if needed. 71% agree 20% disagree

Other answers that were recieved:

Two homes do not have internal plumbing.
Two homes have raw sewage that drains into a ditch.
One home has a septic tank that drains into an old dry well.
Two homes drain raw sewage into a sinkhole.

From this survey data it is apparent that the township residents are concerned about water quality and the proper use and operation of their septic systems. It is important to note that 5% of the residents surveyed have already upgraded their septic systems when it was needed. It was also noted that the majority of the residents are willing to upgrade and help pay for this upgrade if needed. Better than 50% of the residents surveyed have had their septic tanks pumped out more than once since they have lived in their home.

The Waste Water Management Committee feels that through more education and increased contact with township residents we can all improve the water quality issue and remove the building moratorium. Please check your local newspaper for upcomming public meetings that will be held in the next several months. We look forward to meeting you at these meetings.

Sincerely,

Sandra Peacock
Sandra Peacock
Committee Chairperson

Daryl Gross
Daryl Gross
Vice Chairman

Jamie Kreglow
Jamie Kreglow
SWCD Technician

Thompson Township Waste Water Management Committee

Cooperating With the Seneca Soil and Water Conservation District
155 E. Perry Street Tiffin, Ohio 44883

"Providing the Building Blocks for a Better Future"

####IMPORTANT#### ***** YOU MUST INCLUDE A COPY OF YOUR (PAID) SEPTIC CLEANING BILL WITH THIS FORM.******** THIS FORM SHOULD BE FILLED OUT TO THE BEST OF YOUR KNOWLEDGE AND THE INPUT FROM THE SEPTIC TANK CLEANER. COST SHARE MONEY WILL NOT BE PAID UNTIL THIS FORM AND YOUR BILL IS RETURNED TO THE SENECA SWCD 155 E. PERRY ST TIFFIN OHIO 44883.

NAME_______________________________ DATE__________

ADDRESS_____________________________ PHONE__________

CITY/STATE________________OHIO ZIP________

AGE OF HOME: 5YRS 10YRS 15YRS 20YRS 40YRS 60+YRS

LOCATION OF SEPTIC SYSTEM: FRONT YD BACK YD SIDE YD

OTHER____

____

TYPE OF SEPTIC SYSTEM: LEACHFIELD AERATION- is aerator running? YES NO

OTHER____

OF TANKS: 1 2 APPROX SIZE OF TANK(S) ________GAL.
________GAL.

A riser pipe is an above ground pipe above your tank that can be used to see inside of the tank.
DO YOU HAVE A RISER PIPE(S) ON YOUR TANK YES NO
HOW MANY____

HOW MANY PEOPLE LIVE IN YOUR HOME ______

HOW OFTEN SHOULD YOUR SEPTIC TANK BE PUMPED ______________

DO YOU HAVE A WATER SOFTENER THAT EMPTIES INTO YOUR TANK
YES NO
DESCRIPTION OF LEACHFIELD AND (OR) TILE OUTLET DRAWING:
(please use the back of this form for your drawing)

CONDITION OF SYSTEM: REPAIRS NEEDED, REPLACEMENT OF ETC.

____

____

____

THIS INFORMATION WILL BE USED TO ESTABLISH A NEED FOR SEPTIC SYSTEM UPGRADES AND POSSIBLE FEDERAL COST SHARE MONIES. THIS

Jim,
The kits contain
+ toilet dam
+ toilet tank bank
+ showerhead
+ aerator for kitchen + bathroom faucets
+ toilet leak detection tablets
+ toilet water saver divertor "Tankee Clipper"

Ada

WATER SAVER KIT

CONSERVE WATER 4 EASY WAYS:

- **Reduce flow from showers**
- **Reduce flow from faucets**
- **Use less water per flush**
- **Detect toilet tank leaks**

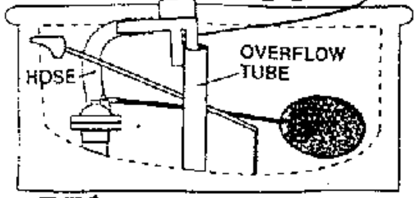
Use this water conservation kit to save water and energy.

2 LEAK DETECTOR TABLETS
INSTRUCTIONS.
1. REMOVE TANK COVER CAREFULLY
2. DROP TABLET IN TANK
3. WAIT SEVERAL MINUTES
4. IF COLOR APPEARS IN BOWL, YOU HAVE A LEAK.

HARMLESS IF SWALLOWED

TOILET WATER SAVER DIVERTOR
Tankee Clipper™

Saves up to .5 gallons per flush and installs in seconds!



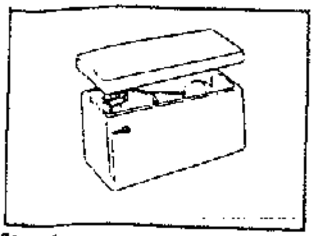
INSTRUCTIONS:
1) Pull hose out from overflow tube.
2) Remove clip or holder, if any.
3) Insert CLIPPER into hose end.
4) Push CLIPPER onto overflow tube with one of its arms inside and one arm outside the overflow tube.
5) In some cases, the hose may need to be cut shorter to reduce buckling or tipping.

Niagara
1-800-831-8383

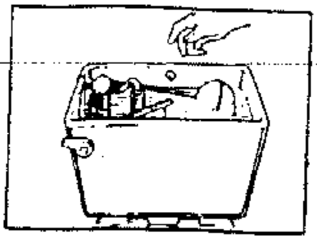
PATENT PENDING

LEAK DETECTION TABLETS:

Savings: Finding and repairing toilet leaks, which can waste over 100 gallons a day (often without making a sound), can be a rewarding experience—worth as much as $100.00 a year in water bill savings.



Step 1
Remove cover from top of toilet tank.



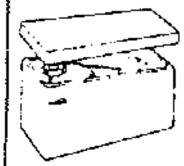
Step 2
Drop tablets into tank and replace cover.

Step 3
Wait ten minutes.

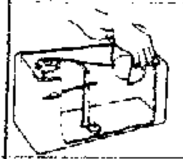
Step 4
If colored water appears in the bowl, you have a leak.

TOILET DAM INSTALLATION

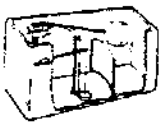
Savings: Your toilets are the largest water-wasters in your home. About 5-7 gallons of water are lost with every flush. Using these Toilet Dams you save 100's of gallons of water per person per year and REDUCE SEWER FLOWS.



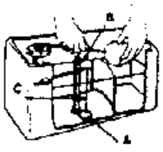
Step 1
Remove cover from top of toilet tank.



Step 2
Bend the Toilet Dam and place next to the drain valve as shown in the diagram. The rubber blade edges should press on bottom and sides of tank. POSITION TOILET DAM SO IT DOES NOT REST ON ANY BOLTS OR OBSTRUCTIONS IN TANK. Toilet Dam should be positioned so it does not interfere with any moving part in the tank.



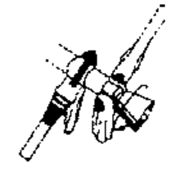
Step 3
Flush the toilet. If the toilet does not flush well after the Dam is installed, move Toilet Dam farther away from drain valve.



Step 4
Check water level in tank. Water level should be 1" below the over-flow tube B. Level can be adjusted by GENTLY bending float arm down.

SHOWERHEAD INSTALLATION

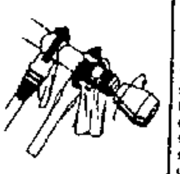
Savings: Hot showers cost you money, both for the water and the energy you use to heat it. This modern, efficient showerhead will help you enjoy a full force shower while you SAVE WATER, cut your energy bill, and REDUCE SEWER FLOWS.



Step 1
Remove old showerhead from the showerarm. If you need to use a wrench to remove the old showerhead, use a second wrench (see illustration) to hold the showerarm while you loosen the old showerhead. Use pieces of cloth to protect the finish.

Step 2
Before installing new showerhead turn on the water to wash out the pipe.

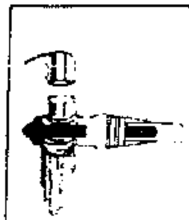
Step 3
TURN OFF WATER. Screw on the new showerhead and hand tighten.



Step 4
Test showerhead. If showerhead leaks, tighten by using a wrench on the showerarm and a second one on the showerhead. Tighten until snug. DO NOT OVER-TIGHTEN.

AERATOR INSTRUCTIONS

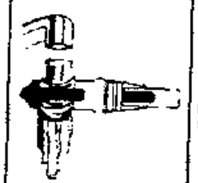
Savings: Your kitchen and bathroom faucets can also cost you money, both for the water and the energy you use to heat it. These highly efficient aerators will give you the rinsing force you need while you save water, cut your energy bill, and REDUCE SEWER FLOWS.



Step 1
Remove old aerator from the faucet. A wrench may be required (see illustration). Use cloth to protect finish.

Step 2
Before installing new aerator, turn on water to wash out faucet.

Step 3
Turn off water. Screw on the new aerator and hand tighten. (Use one rubber washer for faucets with external threads and two washers for faucets with internal threads.)



Step 4
Turn on water. If aerator leaks, tighten by using wrench. Use cloth to protect finish. Tighten until snug. DO NOT OVERTIGHTEN.

PNC0100

APPENDIX D

UNIVERSAL SOIL LOSS AND GULLY EROSION EQUATIONS AND EXAMPLES

Universal Soil Loss Equation

The Universal Soil Loss Equation (USLE) can be adapted to estimate soil savings for different practices.

$$A = RKLSCP$$

where:

A = the predicted average annual soil loss expressed in tons/acre/year

R = the Rainfall factor. It is the number of erosion index units in a normal year's rain. The erosion index is a measure of the erosion force of specific rainfall. When other factors are constant, storm losses from rainfall are directly proportional to the product of the total kinetic energy of the storm times its maximum 30-minute intensity.

K = the Soil Erodability factor. It is the erosion rate per unit of erosion index for a specific soil in cultivated continuous fallow on a 9-percent slope 72.6 feet long. Soil properties that influence erodability by water are (1) those that affect the infiltration rate, permeability and total water capacity, and (2) those that resist the dispersion, splashing, abrasion, and transporting forces of the rainfall and runoff.

L = the slope Length factor. It is the ratio of soil loss from the field slope length to that from a 72.6-foot length on the same soil type and gradient. Slope length is the distance from the point of origin of overland flow to (1) the point where the slope decreases to the extent that deposition begins or (2) the point where runoff enters a defined channel.

S = the Slope gradient factor. It is the ratio of soil loss from the field gradient to that from a 9-percent slope. The relation of soil loss to gradient is influenced by density of vegetal cover and by soil particle size. L and S are combined to make the LS Factor for use in mathematical solution of the USLE.

C = the Cropping-management factor on cropland and other land uses, is the ratio of soil loss from a field with a specified cropping and management or plant cover to that from the fallow condition on which the factor K is evaluated. This factor measures the combined effect of all the integrated cover at the time of the rain.

P = the Erosion Control Practice factor. It is the ratio of soil loss with contouring, stripcropping, or terracing to that with straight row farming up-and-down the slope.

Sinkhole Structure

For each sinkhole structure, the gully equation was modified slightly to accommodate for the circular nature of the structure. The following equation was used:

Vol(cu.ft) = Length(ft.) x 0.5 x avg. circumference(ft) x avg. depth(ft.)

Vol(Tons) = Vol(cu.ft.) x 0.047

Vol(cu.ft.) = 20' x 0.5 x 100' x 0.5 = 500

Vol(Tons) = 500 cu.ft. x 0.047 = 23.5 Tons/yr/structure

The values used in the gully equations were average values for waterways and sinkhole structures installed in Thompson Township.

The following example is for soil savings for conservation tillage verses conventional tillage:

R = 125
K = 0.43 (Glynwood soil is avg soil type for Thompson Township)
Ls = 0.35 (A slope of 3% and length od 200 feet was used as an average)
C = 0.28 (Conventional tillage)
C = 0.14 (Conservation tillage)
P = 1

The soil loss recorded as tons/acre/year for the two types of tillage are:

Conventional tillage - 5.3 T/Ac/Yr

Conservation tillage - 2.6 T/Ac/Yr

Subtracting the two figures results in a soil savings of 2.7 T/Ac/Yr if conservation tillage is used instead of conventional tillage.

Soil Loss From Gully Erosion

To determine soil savings for the grassed waterways and the sinkhole structures, the following equations were used:

Grassed Waterway

Vol(cu. ft.) = Length(ft.) x 0.5 x (avg. top width(ft.) + avg. bottom width(ft.)) x avg. depth(ft.)

Vol (Tons) = Vol(cu.ft.) x 0.047

The top width, bottom width, and average depth measurements refer to the shape of the ditch or waterway.

For a one-foot stretch of waterway the soil savings will be:

Vol(cu.ft.) = 1′ x 0.5 x (6′ + 2′) x 0.5 = 2 cu. ft.

Vol(Tons) = 2 x 0.047 = 0.1 tons/yr/foot of waterway