Proceedings of the Iowa Academy of Science

Volume 87 | Number Article 10

1980

Water Source of Big Spring Trout Hatchery, Clayton County, Iowa

Neill Heitmann

Iowa Conservation Commission

Proc. Iowa Acad. Sci. 87(4):143-147. 1980

Water Source of Big Spring Trout Hatchery, Clayton County, Iowa

NEILL HEITMANN

Iowa Conservation Commission, Elkader, Iowa 52043[1]

A large naturally flowing spring emitting from the Galena Dolomite Formation in the valley wall of the Turkey River, 8 km northwest of Elkader, is the source of water supply for Big Spring Trout Hatchery. Precipitation in northern Clayton County infiltrating the bedrock and moving laterally along crevices and cavities in the dolomite rock is the principal recharge source for the spring. Numerous sinkholes as far as 13.9 km to the north and northeast capture surface runoff and funnel water to the spring. Chemical dyes and plastic spheres were used to trace the groundwater movement from the sinkholes to the trout hatchery. The dye tracers also helped to establish a general groundwater basin boundary for Big Spring. The travel time of the dye tracers varied from 24 to 144 hours and was related to the quantity of water entering the sinks immediately before and after introduction of the dye. All sinkholes were mapped to aid in any future plans to control the amount of soil and other contaminants entering the aquifer.

INDEX DESCRIPTORS: Big Spring, dye tracing, Galena Dolomite, groundwater tracing, karst, sinkholes.

Big Spring Trout Hatchery is located on the banks of the Turkey River, 8 km northwest of Elkader in the NE¼-SE¼-Sec31-T94N-R5W. The facility, operated by the Iowa Conservation Commission, has 24 concrete raceways and 4 earthen ponds used principally for rearing rainbow trout and brown trout. Trout production may vary somewhat, but the Hatchery is operating near its maximum capacity when 260,000 to 270,000 trout are produced yearly.

This hatchery relies entirely on the flow of Big Spring for its water supply. Big Spring flows from the Galena Dolomite Formation and is the largest in Iowa, with a flow rate ranging between 0.32 cms and 0.64 cms (Steinhilber et. al. 1961). There are no additional statistics on flow rates available. Observations by hatchery personnel indicate that a stable, low flow rate occurs during the late winter months and a stable, high flow rate usually occurs between mid-July and mid-September.

It is not uncommon for the flow rate at Big Spring to increase two-fold or more following intense storms in the northern townships of Clayton County. The area has characteristic karst topography with numerous sinkholes (Figure 1) and small cave systems. Because farming is the primary business of this area and soil conservation practices are poorly established on much of this gently to strongly sloping land, gully, rill, and sheet erosion makes silt a major contaminant of the Big Spring aquifer (U.S. Department of Agriculture, 1973). This not only creates a costly and potentially disastrous situation for the Big Spring Trout Hatchery, it also creates a human health hazard for persons utilizing private well water supplies in this area. For example, water entering sinkhole C (Figure 1) was not only traced to Big Spring but also to a farm well in the NW¼-Sec32-T94N-R5W being used as a source for potable water (Heitmann, unpublished). In addition to pollution from farmland runoff, there are potential point sources of pollution such as dairy cooperatives, quarry operations, municipal sewage treatment facilities, and sinkholes used as local dump sites (Heitmann, unpublished) which could be equally damaging.

The monetary loss from a total fish kill at Big Spring Hatchery would now approach $68,900[2], substantially more than the $41,543 loss attributed to the release of effluent from a cheese factory in 1963. The yearly expenditures made for aerator operation and raceway maintenance following heavy rains and spring thaws are a less obvious but continual problem. Approximately $4,393 of production expenses during 1977 and 1978 were attributable to soil erosion from agricultural lands (losses due to trout mortality were not included). Of this total, nearly $3,500 in salaries were expended for 6 clean-up operations requiring an average of 4 hours of labor per raceway. Eight labor-hours or $385 were required to blade the silt which had settled in each of the 4 dirt ponds. More than $508 were paid out for the electricity used in operating aerators during these periods of heavy runoff (17.53 kwh per aerator day at 64 cents per aerator day).

As a result of these continuing problems, the Big Spring sinkhole research project was initiated in April 1977 to find those sinkholes which drain into the Big Spring hydraulic system and contribute to water quality deterioration.

STUDY AREA AND GEOLOGY

The area of greatest concern included the subsurface drainage net which flows to Big Spring and the surface watershed which recharges this section of the Galena aquifer. A general groundwater basin was defined by making dye traces from sinkholes in the Big Spring hydraulic system and from sinks belonging to adjacent spring systems which resurface at Spook Cave and St. Olaf (Figure 1).

The Galena Dolomite and the Maquoketa Shale of Ordovician age are the uppermost bedrock units within this study area. Only the basal part of the Maquoketa Formation, the Elgin Limestone and Shale, generally is present. It caps the uplands, but has been eroded from the valley slopes and bottom lands. A thin mantle of soil, loess, and glacial clay comprises the surficial material. These units, and the other sedimentary rocks of Clayton County, dip toward the southwest (Steinhilber et. al. 1961). Exposures of Silurian age Niagaran Dolomite occur a few miles to the southwest and as small outliers in the vicinity of Gunder. In these locations the full thickness of the Maquoketa Formation occurs. Table 1, as adapted from *Geology and Ground Water Resources of Clayton County* (Steinhilber et. al. 1961), shows the general stratigraphy of these units.

Figure 1. *This map of the study area shows the general location of all sinkholes located during the survey, the results of dye tracings (hypothetical, straight-line flow-paths) and the groundwater basin boundary for Big Spring.* →

[1]Present address: R.R. 1, Keystone, Iowa 52249

[2]Based on 1977-1978 production and distribution costs for 260,000 trout, weighing 0.227 kg each, at $1.17 per kg. Does not include clean-up costs for a total fish kill as does the 1963 figure.

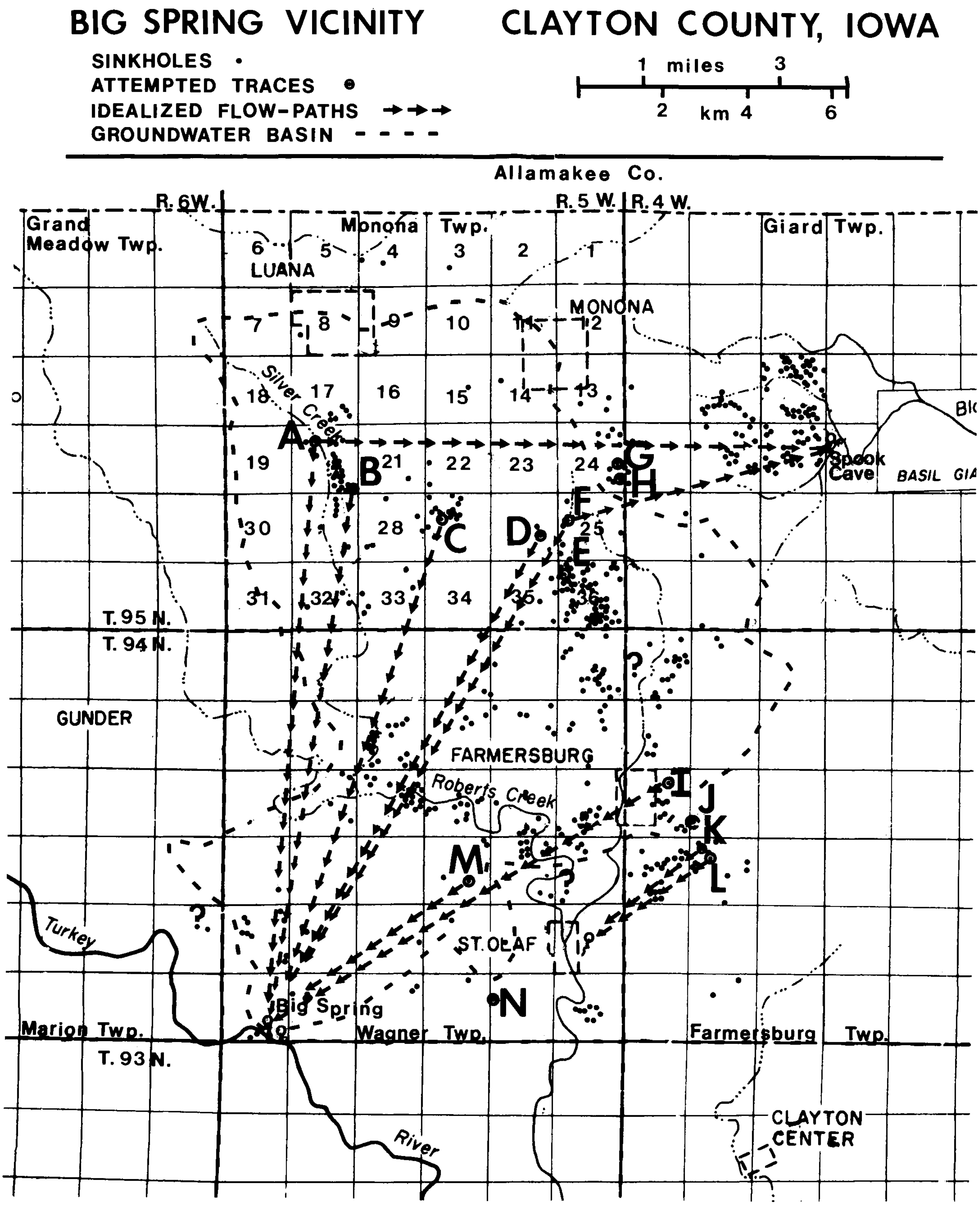
BIG SPRING VICINITY
CLAYTON COUNTY, IOWA
SINKHOLES •
ATTEMPTED TRACES
IDEALIZED FLOW-PATHS
GROUNDWATER BASIN
1 miles 3
2 km 4 6
Allamakee Co.
R. 6W.
R. 5 W.
R. 4 W.
Grand Meadow Twp.
Monona Twp.
Giard Twp.
LUANA
MONONA
Silver Creek
Spook Cave
BASIL GIA
T. 95 N.
T. 94 N.
T. 93 N.
GUNDER
FARMERSBURG
Roberts Creek
ST. OLAF
Big Spring
Turkey
River
Marion Twp.
Wagner Twp.
Farmersburg Twp.
CLAYTON CENTER

Table 1. Generalized section of geologic formations in Clayton County, Iowa (adapted from Steinhilber et. al. 1961. *Geology and Ground Water Resources of Clayton County, Iowa*).

System	Series	Stratigraphic Unit or Formation	Subunit or Member		Maximum Thickness (Feet)
		Recent Deposits			35
		Wisconsin			
Quaternary	Pleistocene	Kansas Drift			135
		Nebraskan Drift			
	Niagaran	Hopkinton Dolomite		125?	190
Silurian		Kankakee Limestone		140?	
	Alexandrian				
		Edgewood Limestone			35
			Brainard Shale		126
	Cincinnatean	Maquoketa Shale	Ft. Atkinson Dolomite		40
			Clermont Shale		40
			Elgin Limestone		110
			Dubuque Dolomite		50
		Galena Dolomite	Stewartville Dolomite		77
			Prosser Limestone		132
			Ion Member		23
	Mohawkian	Decorah Shale	Guttenberg Limestone		27
Ordovician					
			Spechts Ferry Member		18
		Platteville Limestone	McGregor Member		35
			Pecatonica Dolomite		16
			Glenwood Shale		25
	Chazyan	St. Peter Sandstone			112
			Willow River Dolomite		95
	Beekmantownian	Prairie du Chien Formation	Root Valley Sandstone		25
			Oneota Dolomite		215

METHODS AND MATERIALS

Soil survey maps and aerial photos provided by the USDA Soil Conservation Service were examined to find the possible sinkhole sites in each square mile of the study area. Landowners or tenants were located with a recently published farm directory of Clayton County. The study objectives were explained and questions were posed to each landowner. If the sinkholes which appeared on the soil survey maps remained open (some have been closed by landowners) the interviews helped to obtain the following information: number of sinkholes present, number occurring in stream beds or waterways and number with large drainage areas. With the landowners permission, 413 sinks were visited and inspected to verify and add to the interview data. For the sinks which were being used as dump sites, the refuse was listed as a contaminant or a non-contaminant. Materials listed as contaminants in Table 2 pose the possibility of entering the aquifer and draining to Big Spring Hatchery (Heitmann, unpublished) and into nearby domestic wells. From this initial survey information each sinkhole was evaluated for its suitability as a site for introducing a tracing material.

Listed in Table 3 are the chemicals which were used in tracing the groundwater flow-paths from sinkholes. To determine the quantity of a chemical needed for a successful trace the following equation was used (Aley and Fletcher, 1976):

$$W_d = 1.478 \sqrt{DQ/V}$$

Where: W_d = weight of dye in kilograms to be injected
D = straight line distance in kilometers from point of injection to resurgence
Q = quantity of flow in cubic meters per second
V = velocity of flow in meters per hour.

Activated coconut charcoal was used as a medium to adsorb the fluorescein from water passing through it. By placing 12 grams of charcoal in a 7 cm by 12 cm nylon mesh packet the need for taking grab samples was eliminated. Several packets were placed at each sampling

Table 2. *Refuse disposed of by dumping into sinkholes.*

Contaminants	Non-contaminants
Batteries	Brick, plaster, cement
Animal carcasses	Brush, stumps, logs
Domestic garbage	Car bodies
Manure	Hay
Spoiled grains and feed	Lumber
Pesticide cans	Scrap iron
Petroleum cans	Appliances
Veterinary medical supplies	

site so that a sampling frequency of 8-10 hours provided an estimate of the rate of flow through the aquifer.

At each sampling interval the contents of a charcoal packet were emptied into a 75 ml glass container. The fluorescein was then elutriated with a 5%, by volume, solution of KOH in 70%, by volume, isopropanol (Aley and Fletcher, 1976) or with the Smart solution of 43%, by volume, 1-propanol and 57%, by volume, 20% aqueous NH_4OH (Smart, 1972). If fluorescein was present in the sample it appeared above the charcoal as a green haze.

This technique was effective in analyzing samples taken from Big Spring when the water was carrying a large silt load and a high content of organic detritus. However, it is reliable only for qualitative analysis and, according to Smart (1972), should not be used to estimate cumulative concentrations of dye flowing through the sample site.

The presence or absence of Direct Yellow 96 or Fluorescent Brightener 28 in spring water was determined by placing cotton detectors in the water (Quinlan, 1976). When examined under a long-wave ultraviolet light the cotton displayed a yellow fluorescence for Direct Yellow 96, a blue fluorescence for Fluorescent Brightener 28 and a white fluorescence if both dyes were present.

Plastic spheres were also used as a tool for tracing groundwater flow in this karst region. Five hundred color-coded polyethylene spheres (specific gravity 0.94 to 0.95) and 500 polystyrene spheres (specific gravity 1.04 to 1.065) with a diameter of 1.1 cm were introduced into 6 sinkholes (B,C,D,E,F and L of Figure 1).

Table 3. *Dyes used in groundwater tracing for the Big Spring sinkhole research project.*

Brand Name	Colour Index General Name	Colour Index Constitution Number	Manufacturer
Uranine (Sodium fluorescein)	Acid Yellow 73	45350	Fischer Scientific
Fluorescent Yellow Dye (Sodium fluorescein)	Acid Yellow 73	45350	Pylam Products Co. In.
Diphenyl Brilliant Flavine 7GFF	Direct Yellow 96 (DY-96)	Not assigned	CIBA-Geigy Corp.
Calcofluor White ST Solution	Fluorescent Brightener 28 (FB-28)	40622	American Cyanamid Co.

Table 4. *Summary of dye traces made in the Big Spring vicinity.*

Sinkhole Location (Plate 1)	Sinkhole Elevation (meters above sea level)	Straight Line Distance to Spring[1] (kilometers)	Dye Injected And Travel Time (hours)	Velocity of Flow (meters per hour)
A	314	13.9	Fluorescent Yellow Dye (24)	579
B	317	12.7	Uranine (<48)	264
C	317	12.7	Uranine (48)	264
F[2]	323	13.8	Uranine (<72)	192
G	335	15.9 5.0 (Spook Cave)	Uranine (Not Detected)	
H	329	15.1 5.0 (Spook Cave)	DY-96 (Not Detected)	
I	299	10.8	DY-96 (144)	76
J	302	11.0 4.0 (St. Olaf)	FB-28 (Not Detected)	
K	293	3.9 (St. Olaf)	DY-96 (<30)	130
L	299	3.9 (St. Olaf)	Uranine (<30)	130
M	305	5.6	Fluorescent Yellow Dye (41)	137
N	268	5.2	FB-28 (Not Detected)	

[1]Straight line distance to Big Spring, unless otherwise noted. The elevation above sea level, of Big Spring, is approximately 238 m, of the St. Olaf spring about 268 m and of the Spook Cave springs 287 m and 293 m.
[2]There were no dye traces attempted in sinkholes D and E (spheres were introduced in both).

RESULTS

The data obtained from dye tracings are summarized in Table 4. In most of the traces the dye passed through the system as a slug. Initial detector samples were very weakly positive, but within 12 hours were followed by a slug which gave very strongly positive readings. The first positive sample was considered the travel time. As seen in Table 4, there were variations in the travel times for the dye slugs. The distance from a sinkhole to Big Spring appeared to have less of an influence on the travel times of the dyes than the volume of water which entered the sink before and after dye introduction. But it is important to remember that the idealized flow-paths of Figure 1 are hypothetical. They may be similar to the actual plumbing only because they begin at a given sink and resurge at Big Spring. Many factors, including local permeability of the dolomite, silt loads, barometric pressure, and stream levels probably influence the travel time of any tracer.

Generally, when the rainfall for a 12 hour period was less than 5 cm, the runoff which entered a sinkhole would drain to the bottom of the cone and enter the solution channel without backing up. The longest travel times were recorded for dyes introduced under these conditions (sinks F,I,K,L and M, Table 4). During rainstorms of higher intensity, the runoff drained to the sinks but, initially, only part of this volume was funneled into the aquifer. Inflowing runoff then began filling the sinkhole cone. For unexplained reasons, the sink would eventually drain rapidly (from 2-5 seconds). Following this, any runoff which continued to flow into the sink ran directly into the solution channel at its base. The shortest travel times were recorded when the dye was introduced immediately before (sink A) or shortly after (sinks B and C) the flushing occurred.

Dye introduced into 2 of the sinkholes, A and F, resurged both at Big Spring and the Spook Cave springs. In both traces the readings at Spook Cave were weakly positive while the slug passing through Big Spring gave very strongly positive readings. These results suggested that the sinks were near the drainage net boundary of Big Spring and that the sinkholes in the vicinity of sinks G and H would drain to Spook Cave. However, 0.45 kg of Uranine introduced into sinkhole G did not resurge at Spook Cave. Since 0.45 kg of dye would not have been enough for a successful trace to Big Spring, 4.54 kg of Dy-96 was later introduced into sinkhole H. Again, all readings at Big Spring, Spook Cave, and St. Olaf were negative. Because the dye was not recovered, the hydraulics of these sinks are not yet fully understood.

Successful dye traces were made from sinks B, C, and D to Big Spring. Because of the small size of the sinkholes, and the small watersheds associated with them, the sinkholes in sections 8, 14, 15, and 17 of Monona township were not traced.

Successful dye traces were also made from sinkholes I and M to Big Spring and from sinks K and L to St. Olaf. The dye introduced into sinks J and N did not resurge at either Big Spring or St. Olaf. Though it seems likely that these sinks are associated with separate spring systems, the hydraulics are not thoroughly understood.

In sections 23 and 24 of Wagner township lie 3 sinks which were not included in the Big Spring drainage system because of their small watersheds and their proximity to Roberts Creek. The only sinkhole in section 26 of Wagner township was placed within the boundary. This is of limited concern because, as the sinks in sections 23 and 24, it is little more than a surface depression which receives an insignificant amount of runoff.

DISCUSSION

All of the sinkholes listed in Table 4, as well as the sinkholes which were not traced but are considered to be a part of the Big Spring hydraulic system, are plotted on Figure 1. From data obtained in the sinkhole survey and subsequent dye and sphere introductions, idealized, straight-line flow-paths have been established and the proposed boundaries of the Big Spring groundwater basin have been delineated. The groundwater basin boundary is in part, a sinkhole boundary which delineates all major sinkholes that drain to Big Spring. Points where dye traces were not completed are indicated by question marks.

The boundary, as plotted, from Big Spring to Monona is probably quite close to the actual groundwater basin boundary. If the actual boundary, from Big Spring to Farmersburg, does vary from the one indicated in Figure 1 the variation is not extreme and will not cause major complications. The sinks in question are small and take little runoff from surrounding land because of their high relief.

There is some interaction between the Spook Cave system and the Big Spring system. Further study is necessary before the boundary can be more accurately established.

From Monona to Big Spring the boundary becomes more of a sinkhole boundary than a groundwater basin boundary. There may be some groundwater movement from the area north of Luana and Monona and south of the Allamakee County line. Because there are only three minor sinkholes which exist in this area it was not possible to conduct dye traces.

Most of the western boundary is also a sinkhole boundary delineated by the absence of sinkholes in Grand Meadow and Marion townships. It is likely that some recharging of the Big Spring system does occur from the area west of the plotted boundary, but it does not threaten the water quality.

No traces were made from the sinkholes in section 30 of Wagner township but their elevation above sea level, 287 m (940 ft), and their depth below land surface, 24 m (79 ft), suggests that they are a part of the Big Spring system.

Dye traces in Roberts Creek were not completed during this project, but traces should be made at several points from section 25 of Wagner township upstream through section 1 of Marion township.

All of the traces which have been made could be checked and confirmed by constructing a piezometric map for the Galena aquifer in the study area.

With these data, plans may be devised to improve and protect the water quality of Big Spring, a unique natural resource of Iowa. This will require a combined effort between state agencies, federal agencies and landowners. It will help to insure the continued production of an acceptable water supply needed for a high quality trout stocking program.

ACKNOWLEDGEMENTS

I would like to thank Tom Aley, James Quinlan, Roger Koster, Gene Vaughan, Jerry Spykerman, P.J. Horick and the editors of the *Proceedings* for their help and encouragement.

REFERENCES

ALEY, T. and M. W. FLETCHER. 1976. The water tracer's cookbook. *Missouri Speleology*. 16(6):32.

QUINLAN, J. F. 1976. Third international symposium for underground water tracing, papers. 2:257-262.

SMART, P.L. 1972. A laboratory evaluation of the use of activated carbon for the detection of the tracer dye Rhodamine WT. Thesis. University of Alberta, Department of Geography, Edmonton, Alberta. pp. 105-111.

STEINHILBER, W.L., O.J. VAN ECK and A.J. FEULNER. 1961. Geology and ground water resources of Clayton County, Iowa. U.S. Geological Survey and the Iowa Geological Survey. Water Supply Bulletin No. 7. 142 pp.

United States Department of Agriculture and other cooperating agencies. 1973. Upper Explorerland resource conservation and development project, project plan. pp. 24-26.