June 1997 Highway 44--Odessa Spring Traces

by

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SUMMARY

On June 6 1997, three dye traces were initiated from sinkholes D6741, D6742, and D6743 which are located on the north edge of Highway 44. The sinkholes are 2.23, 1.28, and 0.38 miles west of Highway 44's junction with Minn. Highway 139 on the south edge of Harmony Minn. Flow from sinkholes D6741 and D6742 resurged at Odessa Spring in four to six days. Odessa Spring is on the Upper Iowa River about 3.5 miles southwest of that segment of Highway 44. The third dye washed into sinkhole D6743 was not detected as any of the monitoring sites as of July 8, 1997.

None of the dyes were detected in the upper or lower underground streams in Niagara Cave.

INTRODUCTION

S.J. Louis Construction, Inc. as part of their S.A.P. 23-644-03 Fillmore County project authorized in a letter dated June 5, 1997 dye traces of three of the sinkholes along the eastern segment of County Road 44 in Fillmore County. These three traces were made in June of 1997 by the Geology and Geophysics Department of the University of Minnesota in cooperation with Jeffrey A. Green of the Minnesota Department of Natural Resources, Rochester. The purpose of the traces were twofold: 1) to determine where water which sinks into sinkholes along and under County Road 44 resurges, and 2) to check the possibility that repaving of County Road 44 might affect the underground streams in Niagara Cave. This document reports the results of those three traces.

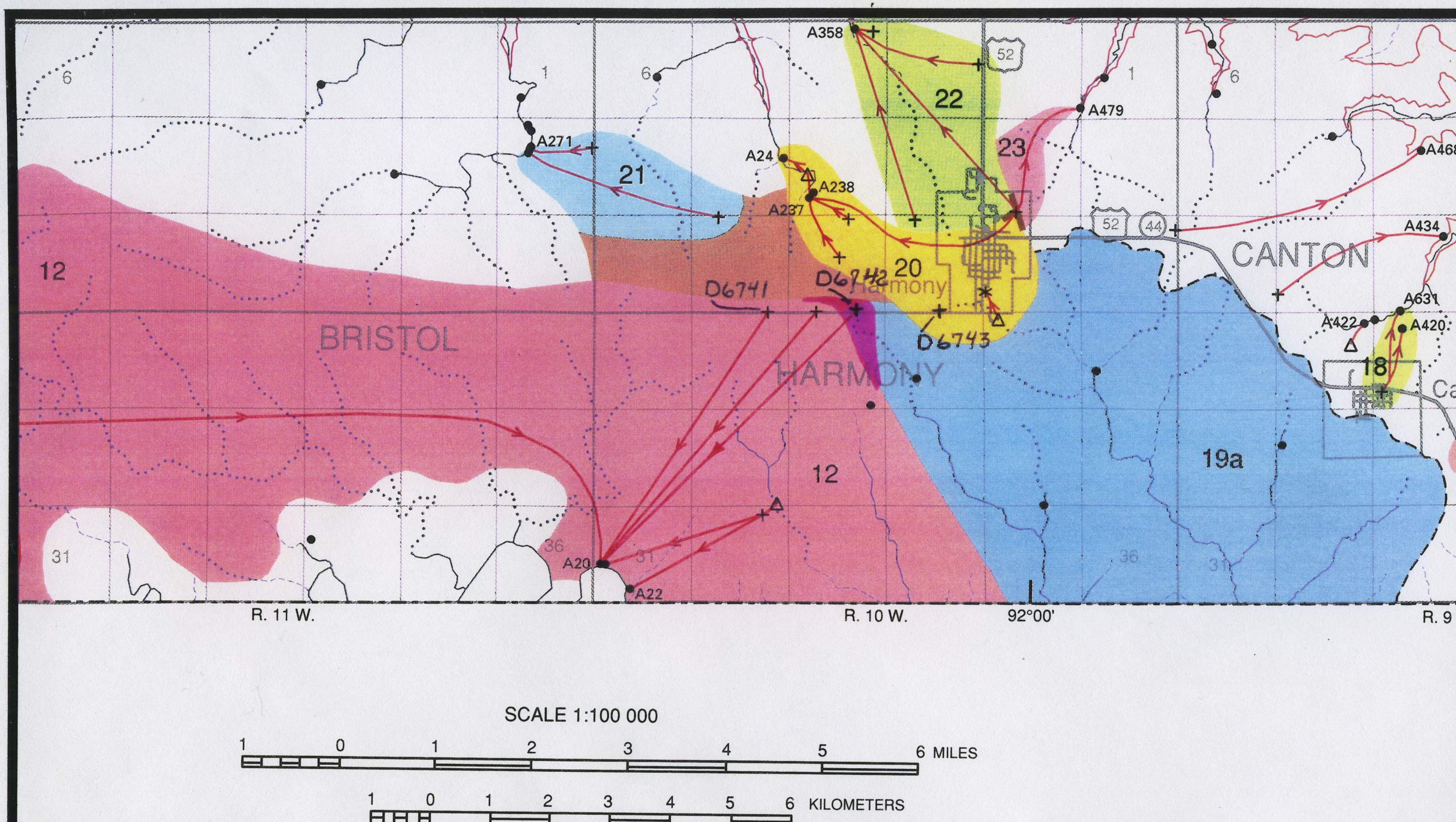
BACKGROUND

Highway 44 connects US Highway 63 south of Spring Valley with Minn. Highway 139 south of Harmony. This stretch of Highway 44 runs east/west over some of the most visible karst terrain of Fillmore Co. (Witthuhn and others, 1995; Alexander and others, 1995; Alexander and Lively, 1995). Alexander and others (1995) Springshed map indicates that most of this segment of Highway 44 is in the Odessa (SH12) and York (SH12a) Springsheds, both of which resurge at Odessa Spring (A20) on the Upper Iowa River in section 31 of Harmony Township. The 17 miles of County Road 44 between US 63 and Minn. 139 are currently being regraded and repaved. There are a number of sinkholes under and immediately adjacent to Highway 44 and drainage into these sinkholes is a potential source groundwater pollution.

Figure 1 contains a section of the Alexander and others (1995) Fillmore County Springshed map covering most of Bristol Township, all of Harmony Township and much of Canton Township. The four mile stretch of Highway 44 immediately west of the junction with Minn. 139 on the south edge of Harmony lies over a complex boundary between four springsheds according to Alexander and others (1995) map and is in an area with a high density of sinkholes. All of the surface and subsurface drainage in this area is via and into the karst groundwater system.

Two traces shown on Alexander and others (1995) map originated from sinkholes adjacent to Highway 44. One trace originated from a culvert that apparently drains to a sinkhole under Highway 44. This culvert, "MNDOT #3", is on the north side of Highway 44 2.23 miles west of the junction with Minn. 139. The second trace was from a sinkhole 1.70 miles west of the junction with Minn. 139. Both traces resurged at Odessa Spring (A20 in Figure 1). The streams in Niagara Cave were not monitored during these traces but Niagara Cave is roughly half way between Highway 44 and Odessa Spring.

Niagara Cave is a commercial show cave located about two miles south and two miles west of Harmony. Niagara is about two miles south of Highway 44. Two segments of underground streams are a prominent part of the Niagara Cave tour. A trace of the streams in Niagara Cave resurged at both Odessa Spring and Hawkeye Spring (A22 in Figure 1).



Ground water flow paths—The lines show **diagrammatically** the flow paths and directions of mapped underground rivers. Most lines connect the input and exit points of positive traces. The lines do not necessarily show the actual locations of the conduits.

Upper Carbonate Aquifer

Springs—Resurgence springs of springsheds are identified by number and listed in Table 1. Only a few of the many other springs in the county are shown.

A24

Sinkholes—Only those few sinkholes used as tracer input sites are shown. See the Fillmore County Sinkhole data base and Plate 8 for more locations and other information on sinkholes.

● Coldwater Spring

Figure 1. Groundwater Springsheds in southcentral Fillmore County, Minnesota

METHODS

Springsheds are constructed in large part based on underground stream tracing. Underground stream tracing involves the introduction of a tracer, often a fluorescent dye, into a stream sink or sinkhole and the subsequent detection of that tracer in one or more springs. Mohring (1983), Mohring and Alexander (1986) and Alexander and Quinlan (1992) describe the techniques used to trace dye inputs in Fillmore County. Two complementary modes of dye tracing were used in this investigation. Either the dyes were detected qualitatively with packets of charcoal that were placed in the springs for varying lengths of time and then analyzed, or the dyes were quantitatively analyzed in water samples collected directly from the springs. The dye in both charcoal packets and water samples was determined using scanning spectrofluorophotometry at the University of Minnesota.

Background Sampling: A network of sampling points was established. The basic idea was to ring the input locations so that the dyes could be detected whichever way(s) they moved. The monitoring points are listed in Table 1 and seen can be seen in Figure 1. Charcoal detectors were placed downstream of six surface springs: Odessa (A20) and Hawkeye (A22) Springs on the Upper Iowa River in section 31 of Harmony Township; Engle (A271) Spring which is the headwaters of Willow Creek in section 12 of Bristol Township, Big (A24) Spring which is the headwaters of Camp Creek in sections 8 & 9 of Harmony Township, Hart (A358) Springs which are the headwaters of Partridge Creek in section 4 of Harmony Township, and Coldwater Spring which is 7 miles south and 3 miles east of Harmony in section 31 of Burr Oak Township in Iowa. The approximate location (at the scale of the rest of the map) of Coldwater Spring is shown in the lower right-hand corner of Figure 1.

Two charcoal detectors were placed in the streams of Niagara Cave. (Niagara Cave is the "+" symbol in section 32 of Harmony Township about 1/2 mile southwest of the "12" in the large pink area in Figure 1). One was placed in the upper level stream where it first enters the cave. The second detector was placed in the lower level stream at the end of the commercial tour.

Background sampling began a week before the dye was injected. No significant backgrounds were encountered.

Dye Input: On June 6,1997 three separate dyes were washed into three separate sinkholes along Highway 44. The sinkholes are on the north side of Highway 44. Sinkhole D6741, "MNDOT #3", 2.23 miles west of the junction with Minn. 139. D6742 and D6743 are 1.28 miles and 0.38 miles respectively west of the junction of Minn. 239. Fluorescein (CAS# 518-47-8, 1.35 kg of uranine liquid dye, 10:40 AM), eosin (CAS# 17372-87-1, 1.10 kg, 10:00 AM), and Rhodamine WT (CAS# 37299-86-8, 2.36 kg of a 20 wt % solution, 9:30 AM) were washed into D6741, D6742, and D6743 respectively. The Harmony Fire Department provided three 1500 gallon truck loads of water for washing the dyes into the sinkhole. At each sinkhole about 500 gallons were released to "wet down the plumbing", the dye was poured into the bottom of the sinkhole, and then the remaining 1000 gallons used to wash the dye into the subsurface. All three sinkholes took the water as rapidly as the fire truck could pump the water.

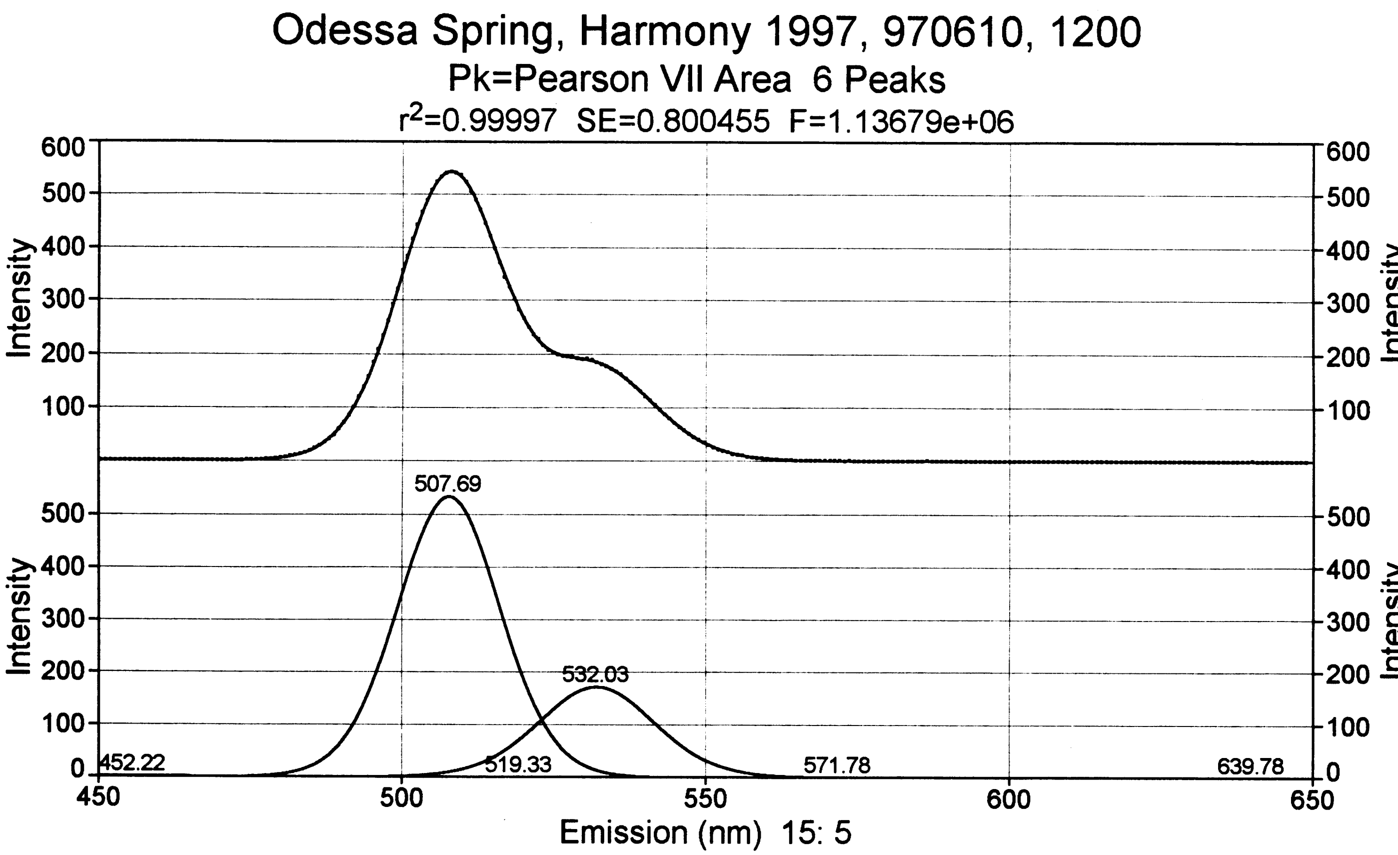
Table 1. Dye Monitoring and Input Points.

MSS ID #	Name	UTM N (NAD 27)	UTM E (NAD 27)	Twp,Rng,Sec,quarters
Monitoring	**Points**			
MN23:A0020	Odessa Spring	4817.257	573.733	T101N,R10W,31,CBBDB
MN23:A0022	Hawkeye Spring	4816.845	574.228	T101N,R10W,31,CDACB
Iowa	Coldwater Spring	4810.17	584.61	T100N,R9W,31,ABADCB
MN23:A0358	Hart Spring	4826.163	577.818	T101N,R10W,04,ABACA
MN23:A0024	Big Spring	4824.015	576.668	T101N,R10W,08,ADDAB
MN23:A0271	Engle Spring	4824.113	572.488	T101N,R11W,12,BDBDB
MN23:C0002	Niagara Cave	4818.11	576.38	T101N,R10W,32,ABADAC
Dye Input	**Points**			
MN23:D6741	"MNDOT #3"	4821.46	576.38	T101N,R10W,17,DDCCDD
MN23:D6742	---	4821.48	577.90	T101N,R10W,16,DCDDCD
MN23:D6743	---	4821.51	579.54	T101N,R10W,15,DCDDDC

Spring Monitoring: Background charcoal detectors were placed and changed before the dye was released in the sampling points. These collectors were periodically changed during the rest of June. On June 5 (when the dyes were washed into the sinkholes) two automatic water samplers were placed at Odessa Spring and water samples were collected every 8 hours for three weeks. Charcoal detectors were also maintained in Odessa while the water samplers were installed.

RESULTS

The fluorescein and eosin from the more western dye inputs, D6741 and D6742, went to Odessa Spring. Figure 2 shows the results of the scanning spectrofluorophotometric analysis of the water sample collected from Odessa Spring at 12:00 noon on June 10, 1997. The top curve is the data. The lower curves are the spectral decomposition of the top curve into individual peaks. The prominent peak labeled "507.69" is the fluorescein peak (in water) and the apparently smaller peak labeled "532.03" is the eosin peak. Eosin is less fluorescent than fluorescein and the two peaks both correspond to about 30 ppb of the respective dyes. A sheet analogous to Figure 2 is generated for each of the charcoal detectors and water samples analyzed. Table 2 contains the results of the analyses of the water samples from Odessa Spring.



Description: Odessa Spring, Harmony 1997, 970610, 1200
X Variable: Emission (nm) 15: 5
Y Variable: Intensity
File Source: a:\od101200.prn

Fitted Parameters

r^2 Coef Det	DF Adj r^2	Fit Std Err	F-value
0.99996972	0.99996871	0.80045466	1.1368e+06

Peak	Type	a_0	a_1	a_2	a_3
1	Pearson VII Area	105.973990	452.222222	35.5555556	0.95749282
2	Pearson VII Area	11499.4312	507.690547	19.9105015	12.8028401
3	Pearson VII Area	9.38816245	519.333333	24.8888889	2.53836820
4	Pearson VII Area	4226.50121	532.032914	22.5604249	9.07003701
5	Pearson VII Area	11.3230230	571.777780	44.4444440	8.38306790
6	Pearson VII Area	95.5026337	639.777778	137.130958	3.10628349

Measured Values

Peak	Type	Amplitude	Center	FWHM	Asym50	Int Area	% Area
1	Pearson VII Area	1.83809442	452.222222	35.5555556	1.00000000	52.5947295	0.33180165
2	Pearson VII Area	533.709403	507.690547	19.9105015	1.00000000	11499.4283	72.5458475
3	Pearson VII Area	0.32044030	519.333333	24.8888889	1.00000000	9.37233873	0.05912679
4	Pearson VII Area	171.872991	532.032914	22.5604249	1.00000000	4226.50086	26.6635071
5	Pearson VII Area	0.23324702	571.777778	44.4444440	1.00000020	11.3174542	0.07139784
6	Pearson VII Area	0.60479640	639.777778	137.130958	1.00000000	52.0427124	0.32831916
	Total					15851.2564	100.000000

Figure 2. Scanning spectrofluorophotometric analysis of the water sample collected from Odessa Spring at 12:00 noon on June 10, 1997.

Table 2. Eosin and fluorescein concentrations in Odessa Spring water samples.

Date	Time	eosin time	fluor. time	eosin (ppb)	fluor. (ppb)
06/05/97	10:00	0.00			
06/05/97	10:40	0.03	0.00		
06/09/97	04:00	3.75	3.72	0.01	0.01
06/09/97	12:00	4.08	4.06	0.77	6.28
06/09/97	20:00	4.42	4.39	19.23	30.21
06/10/97	04:00	4.75	4.72	29.91	29.19
06/10/97	12:00	5.08	5.06	16.95	15.75
06/10/97	20:00	5.42	5.39	8.65	7.90
06/11/97	04:00	5.75	5.72	5.26	5.03
06/11/97	12:00	6.08	6.06	3.32	3.07
06/11/97	20:00	6.42	6.39	2.23	1.97
06/12/97	04:00	6.75	6.72	1.58	1.36
06/12/97	12:00	7.08	7.06	1.23	0.99
06/12/97	20:00	7.42	7.39	0.79	0.67
06/13/97	04:00	7.75	7.72	0.61	0.48
06/13/97	12:00	8.08	8.06	0.50	0.38
06/13/97	20:00	8.42	8.39	0.42	0.27
06/14/97	04:00	8.75	8.72	0.39	0.23
06/14/97	12:00	9.08	9.06	0.39	0.20
06/14/97	20:00	9.42	9.39	0.30	0.16
06/15/97	04:00	9.75	9.72	0.28	0.14
06/15/97	12:00	10.08	10.06	0.23	0.13
06/15/97	20:00	10.42	10.39	0.23	0.12
06/16/97	04:00	10.75	10.72	0.22	0.11
06/16/97	12:00	11.08	11.06	0.20	0.10
06/16/97	20:00	11.42	11.39	0.18	0.09
06/17/97	04:00	11.75	11.72	0.17	0.09
06/17/97	12:00	12.08	12.06	0.16	0.09
06/17/97	20:00	12.42	12.39	0.16	0.08
06/18/97	04:00	12.75	12.72	0.14	0.08
06/18/97	12:00	13.08	13.06	0.12	0.07
06/18/97	20:00	13.42	13.39	0.11	0.07
06/19/97	04:00	13.75	13.72	0.11	0.07
06/19/97	12:00	14.08	14.06	0.11	0.07
06/19/97	20:00	14.42	14.39	0.11	0.08
06/20/97	04:00	14.75	14.72	0.11	0.08
06/20/97	12:00	15.08	15.06	0.12	0.09
06/20/97	20:00	15.42	15.39	0.15	0.10
06/21/97	04:00	15.75	15.72	0.14	0.10
				95.61	105.92

Figure 3 shows the breakthrough curve for the water samples at Odessa Spring for June 5 to 21, 1997. The horizontal scale is time after the dye input and the vertical scale is a linear concentration scale in part per billion (ppb, 10^{-9} g/g). The fluorescein and eosin began to arrive at Odessa Spring early on the 4th day after dye input, peaked at about five days after dye input, and dropped of thereafter. The bulk of the dye reached Odessa Spring during the 4th to 6th day after dye input.

Figure 4 shows the same breakthrough data that are shown in Figure 3 but the vertical concentration scale is a log scale of the dye concentration. Figure 4 illustrates that while the bulk of the dye came out in a three day period, a small but detectable tail of the dye continued to be detectable in Odessa over two weeks after the dye input. The charcoal detectors from Odessa Spring yield qualitative results consistent with the water samples.

No evidence of the fluorescein or eosin from sinkholes D6741 or D6742 was detected at any of the other sampling points. Specifically, no evidence of the dye from the two sinkholes was detected at either of the monitoring points in Niagara Cave.

The Rhodamine WT washed into D6743 has not been detected at any of the monitoring points as of July 8, 1997.

DISCUSSION

The results of the traces from Sinkholes D6741 and D6742 are consistent with the earlier traces summarized in Alexander and others (1995). Sinkholes D6741 and D6742 feed into part of the conduit system that resurges at Odessa Spring. The similarity of the two breakthrough curves and arrival times is evidence that water sinking into these two sinkholes joins a common conduit close to the sinkholes and then travels to the spring along a common path. The travel time under the flow conditions present in the first half of June 1997 was about 4 to 6 days with a significant tail that extended at least two weeks. Under wet, high flow conditions the travel time is expected to be shorter. Under dry, low flow conditions the travel time may be somewhat longer. Any runoff from the Highway 44 in the vicinity of these two sinkholes will reach Odessa Spring in a few days.

No evidence of the dyes washed into Sinkholes D6741 or D6742 was detected in Niagara Cave. The flow system connecting Sinkholes D6741 and D6742 to Odessa Spring does not appear to affect Niagara Cave.

Possible interpretations of the nondetection of the tracer washed into Sinkhole D6743 are limited. Lack of information is not evidence of the absence of a connection. Groundwater traces in which the tracer is not found are fundamentally ambiguous. There are three classes of reasons why tracers are not detected: 1) the tracer emerged at some unmonitored location, 2) the tracer has not yet reached the monitoring locations, or 3) something (dilution, sorption, chemical reaction, etc.) happened to the tracer before it reached the monitoring locations. All three types of explanations are significant possibilities in this case. We note that a number of the sinkholes immediately around D6743 hold water and are semi-perennial ponds. The conduit systems

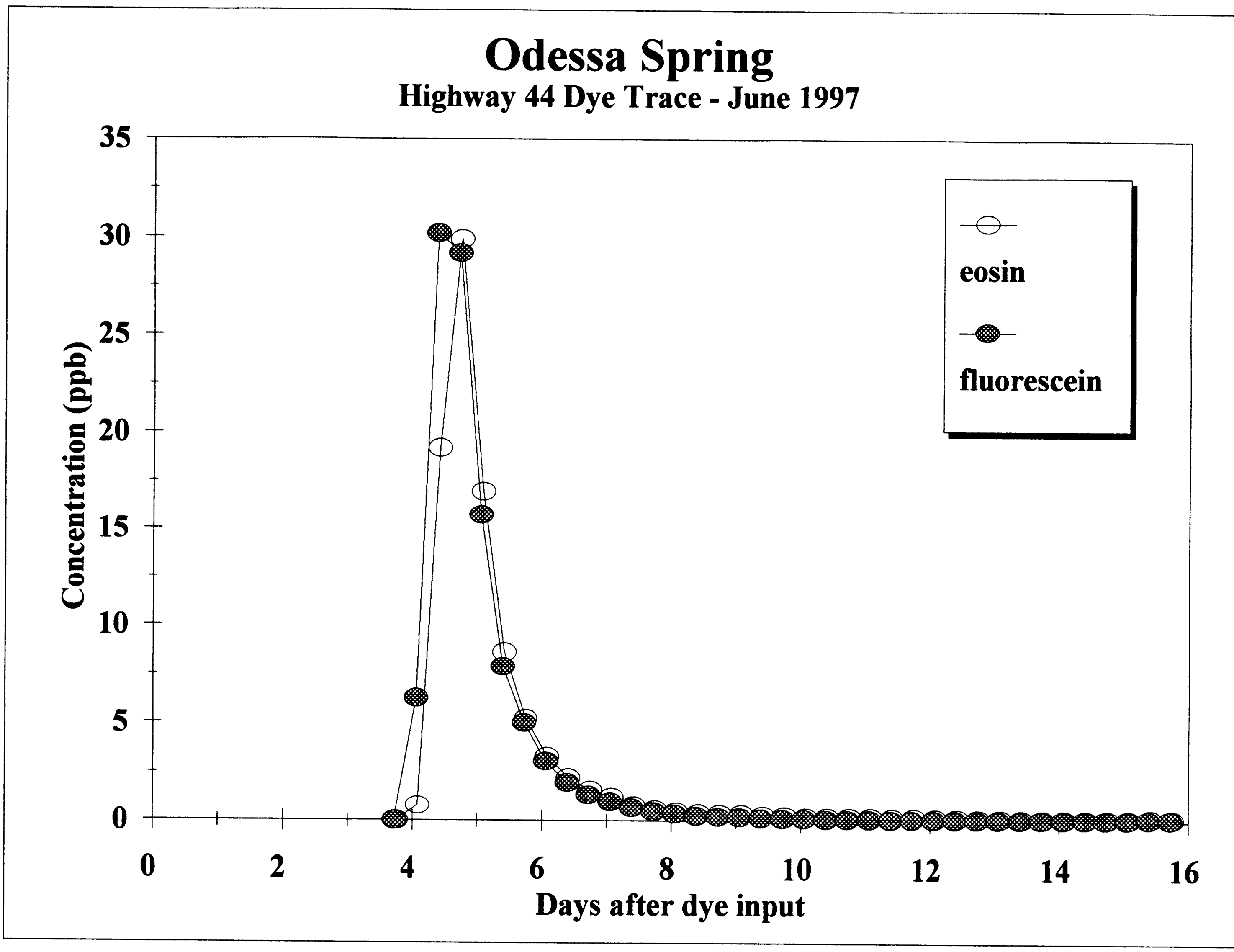


Figure 3. Breakthrough curve with linear concentration scale

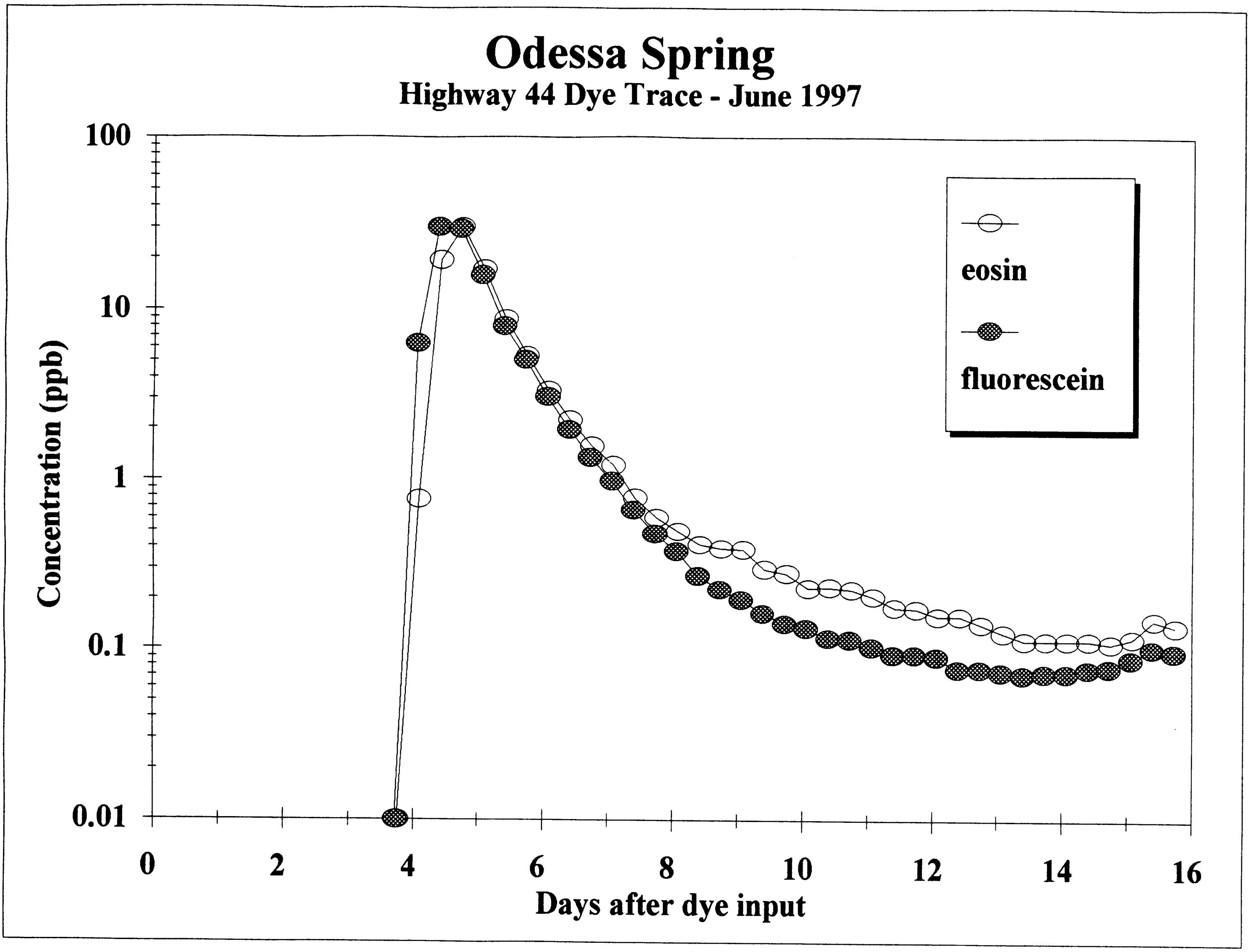


Figure 4. Breakthrough curve with log concentration scale.

beneath the area around D6743 may not be as well integrated as those a mile further west and the karst drainage may be significantly slower. However, the absence on Rhodamine WT at all monitoring sites demonstrates only that we do not know where the water entering D6743 returns to the surface. Only additional work can resolve this issue.

Acknowledgments: We thank Mark Bishop the owner of Niagara Cave for permission to place charcoal detectors in Niagara and change them periodically. We thank Stuart Morem of the Harmony Volunteer Fire Department for trucking the three loads of water to the sinkholes. We thank Wayne Warnke for permission to sample Odessa Spring. We thank Norton Johnson for permission to cross his farm to access Odessa Spring.

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