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Dickson County Landfill

TDSF # 22-507

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**APPENDIX B
USGS DYE TRACER STUDY**

Summary and Results of Dye-Tracer Tests
Conducted at the Dickson County Landfill,
Tennessee, 1997 and 1998

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EXECUTIVE SUMMARY

In April 1997, trichloroethylene (TCE) was detected in water from a production well (Dk-21) operated by the City of Dickson and located near the Dickson County landfill. Results of previous investigations conducted during summer and fall conditions when well Dk-21 was not in use indicate that the well is upgradient from the landfill, and migration of contaminants from the landfill to the well is unlikely. However, when well Dk-21 was used as a water supply (generally December to April of each year), there may have been as much as 40 feet of drawdown in the well, possibly causing a change in the direction of the gradient between the landfill and the well. A dye-tracer study was conducted from December 1997 through September 1998 to help evaluate whether the landfill was a possible source of the contaminants. Well Dk-21 was pumped intermittently during the first half of the study period, and the second half of the study was conducted under non-pumping conditions.

The dye-tracer study was conducted in two phases: a background phase and a dye-detection phase. The background phase, conducted from 12/02/97 to 1/13/98, was used to aid in choosing specific dyes to inject at the beginning of the dye-detection phase. During the background phase, cotton and charcoal dye detectors were placed at 25 sites in the Dickson County landfill area (table 1 and fig. 1). Dye detectors were collected and replaced every one to two weeks during this period and analyzed for dyes that were potentially present in the ground-water and surface-water systems in the area before injection. At the beginning of the dye-detection phase, conducted from 1/13 to 9/29/98, a different dye was injected at each of three points at the Dickson County landfill (tables 1 and 2, figs. 1 and 2). Cotton and charcoal dye detectors at the 25 sites were collected and replaced at intervals spanning from every couple of days at the beginning of this phase to once every 3 weeks at the end of the study. Some of the detection sites were permanent fixtures during the course of the study, but others were abandoned near the end of the study period due to lack of potential dye retrieval. Also, no cotton dye detectors were used after July 1998 because all injected dyes could be absorbed by charcoal detectors. Information pertaining to dye analyses and collection dates for specific dye detectors is contained in Appendix 1.

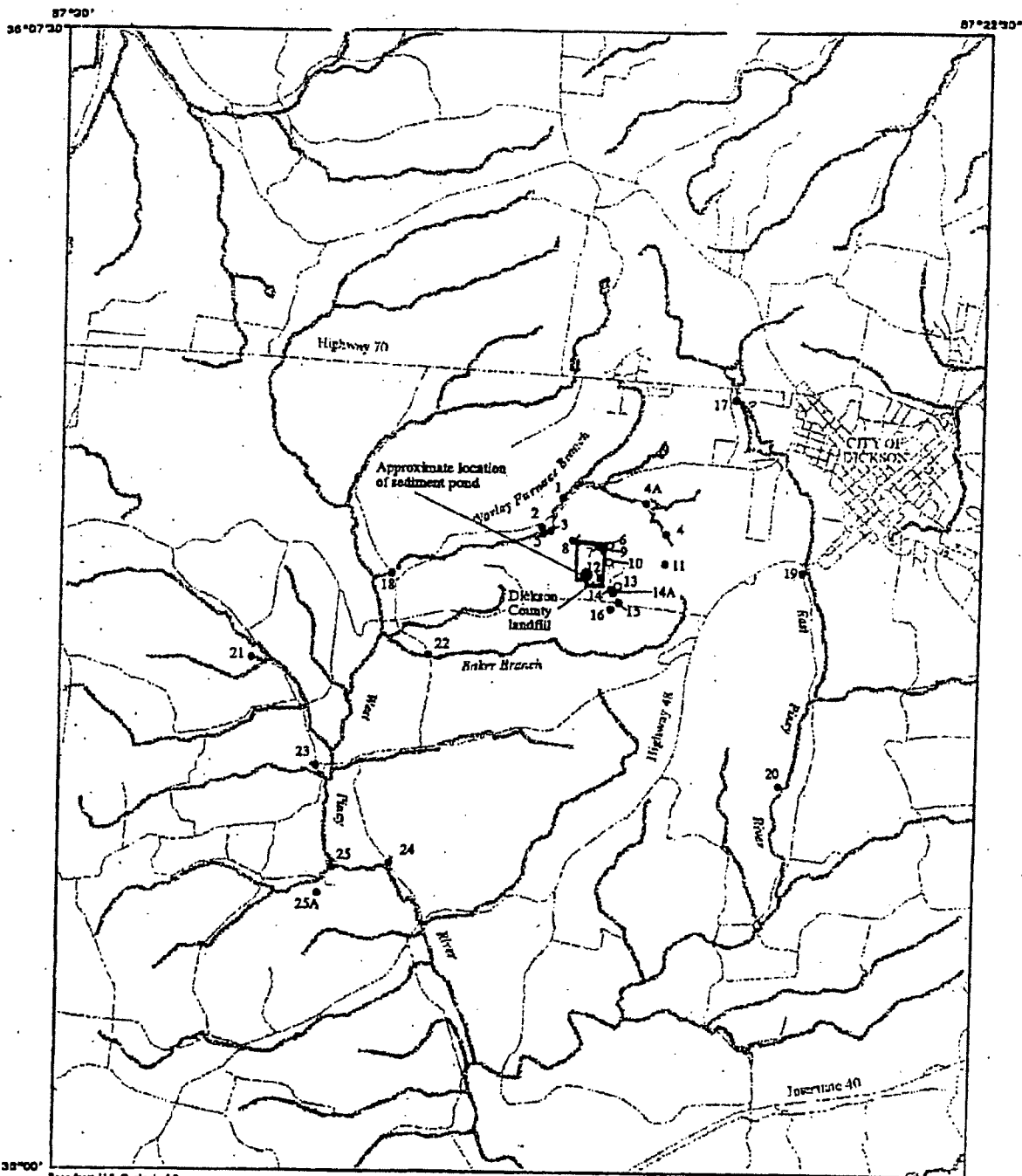
Only one of the injected dyes was positively detected throughout the course of the study. Tinopal CBS-X was positively recovered on 1/14/98 (the day after injection) on both cotton and charcoal detectors at site 8 (table 1, figs. 1 and 2). No other injected dyes were detected at any of the other 24 sites. Although negative tracer recovery does not conclusively disprove the lack of hydraulic connection between the dye-injection and dye-detection sites, none of the dye-tracer tests provided evidence that the landfill is hydraulically connected to Sullivan Spring, the Sullivan well, well Dk-21, or any other of the dye-detection sites not lying in the immediate vicinity of the landfill.

Table 1. Locations of dye-injection and -detection sites in the Dickson County landfill area

Site number (see fig. 1)	Site name	Location		Site type (I=Injection, D=detection)
		Latitude ° ' "	Longitude ° ' "	
1	Baptism Rock, Worley Furnace Branch	36 04 27	87 25 56	D
2	Sullivan well	36 04 16	87 26 06	D
3	Near Sullivan Spring	36 04 14	87 26 02	D
4	Well Dk-21	36 04 13	87 25 05	D
4A	Worley Furnace Branch, downstream of lake	36 04 25	87 25 16	D
5	Sullivan Spring	36 04 13	87 26 05	D
6	Well Dk-88	36 04 09	87 25 33	I
7	Roadside pond	36 04 08	87 25 38	D
8	Well Dk-91	36 04 11	87 25 51	D
9	Wet depression	36 04 07	87 25 36	D
10	County landfill leachate well (LW 4)	36 04 02	87 25 33	I
11	Armstrong well	36 04 02	87 25 06	D
12	Wetlands at sump	36 03 56	87 25 37	D
13	City landfill leachate well	36 03 53	87 25 29	I
14	Cattails	36 03 51	87 25 32	D
14A	Humane Society	36 03 50	87 25 31	D
15	Well Dk-9	36 03 46	87 25 28	D
16	Huddleston, under tree	36 03 44	87 25 32	D
17	Payne Spring	36 05 06	87 24 32	D
18	Worley Furnace Branch, near mouth	36 03 57	87 27 17	D

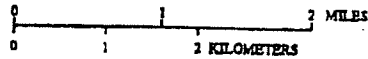
Table 1. Locations of dye-injection and -detection sites in the Dickson County landfill area, continued

Site number (see fig. 1)	Site name	Location		Site type (I=injection, D=detection)
		Latitude ° ' "	Longitude ° ' "	
19	Tice Spring	36 03 59	87 23 57	D
20	Donegan #2 Spring	36 02 34	87 24 06	D
21	Donegan Spring	36 03 24	87 28 26	D
22	Baker Branch, near mouth	36 03 25	87 26 59	D
23	Redden Spring	36 02 41	87 27 53	D
24	Bruce Spring	36 02 02	87 27 16	D
25	Fielder Spring	36 02 00	87 27 44	D
25A	Somerall Spring	36 01 50	87 27 51	D



Base from U.S. Geological Survey
digital line graph, 1:100,000

EXPLANATION

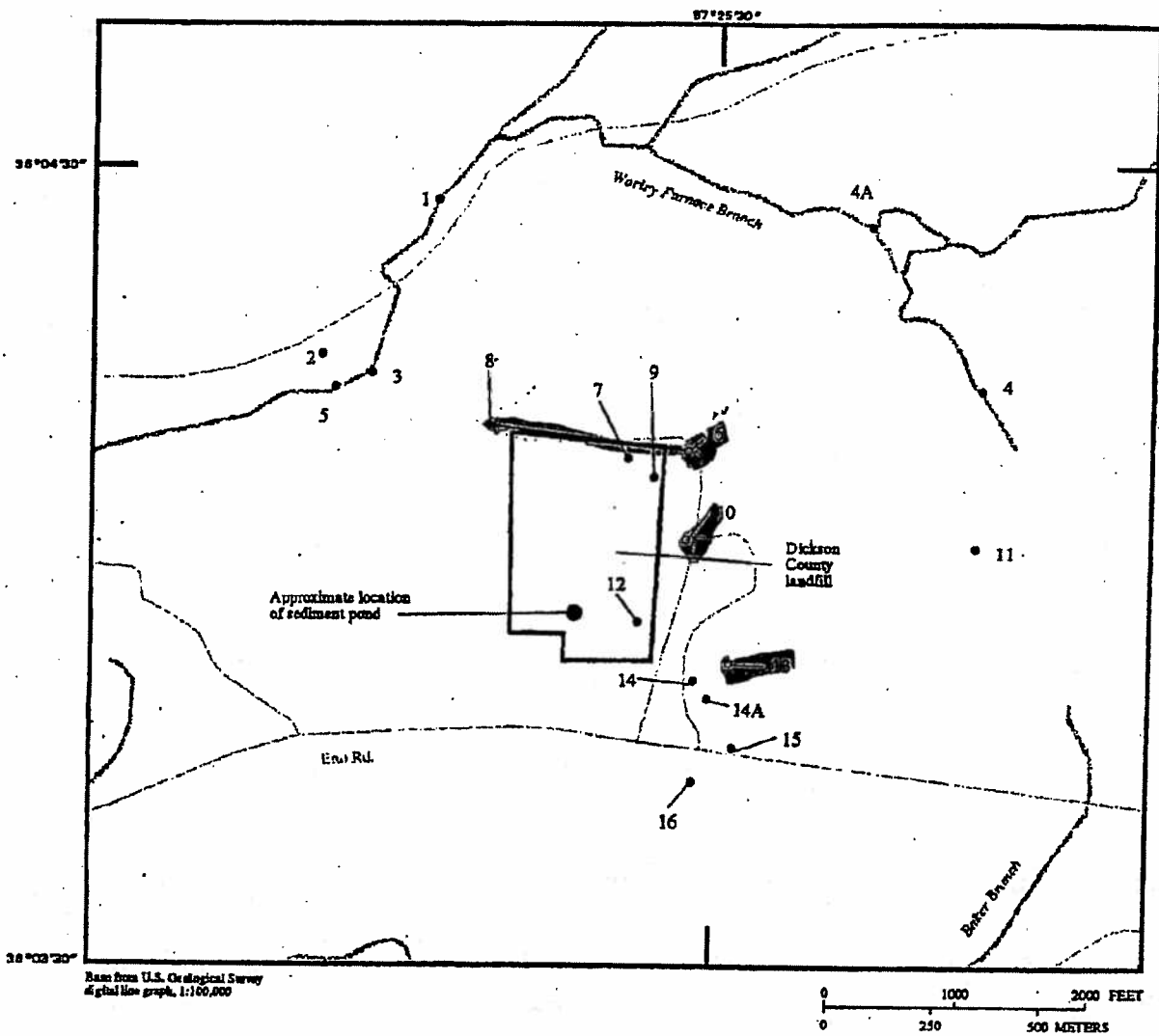


- 13 DYE-INJECTION SITE AND NUMBER
- 25A DYE-DETECTION SITE AND NUMBER
- ← POSITIVE DYE TRACE → Arrow points from dye-injection site to dye-detection site

Figure 1. All dye-injection and -detection sites and a positive dye trace in the Dickson County landfill area.

Table 2. Dye-injection data for dye-tracer tests at the Dickson County landfill

Site number (see figs. 1 and 2)	Location		Depth of well, in feet below land surface	Type of dye injected
	Latitude ° ' "	Longitude ° ' "		
6	36 04 09	87 25 33	104.7	Tinopal CBS-X
10	36 04 02	87 25 33	16	Rhodamine WT
13	36 03 53	87 25 29	12	Eosine OJ



EXPLANATION

- 13 DYE-INJECTION SITE AND NUMBER
- 16 DYE-DETECTION SITE AND NUMBER
- ← POSITIVE DYE TRACE — Arrow points from dye-injection site to dye-detection site

Figure 2. Dye-injection and -detection sites near the Dickson County landfill.



United States Department of the Interior

U.S. GEOLOGICAL SURVEY

To: David Ladd, Hydrologist, Nashville, TN
From: Charles J. Taylor, Hydrologist, Louisville, Kentucky
Date: January 8, 1999
Subject: Analytical results of dye-tracer tests done at Dickson County Landfill, Tennessee

This letter describes the results of dye-tracer tests conducted in 1998 as part of the investigation of ground-water flow at the Dickson County Landfill, Tennessee. Three fluorescent dyes: Tinopal CBS-X optical brightener, Rhodamine WT, and Eosine OJ, were injected in leachate monitoring wells in the northern, central, and southern parts of the landfill on January 13, 1998. These dyes are non-toxic to humans, have low toxicity or mutagenicity characteristics to aquatic life, and have absorptive affinities suitable for recovery in natural waters using passive detectors composed of charcoal and (or) cotton (Smart and Laidlaw, 1977). Eosine OJ and Rhodamine WT tracer dyes are absorbed only by charcoal detectors, while Tinopal CBS-X optical brightener is absorbed by both cotton and charcoal detectors. Different analytical techniques, described below, were used to test for positive recovery of tracer dyes on the different types of detectors.

Laboratory Procedures:

In the laboratory, both cotton and charcoal dye detectors were individually rinsed under a stream of warm tap water to remove accumulated sediment. Detectors were labeled with an identification tag (the site identification number and date of recovery) immediately upon removal from the individual ziplock bags. The detectors were then washed and placed on a table on separated paper towels to air dry overnight.

Analysis of Cotton Detectors

The presence of Tinopal CBS-X optical brightener was determined by direct examination of cotton dye detectors under short-wave ultraviolet radiation (UV) in a darkened room. Undyed cotton detectors appear purplish-black under short-wave ultraviolet radiation. If optical brightener is present, the cotton fluoresces a distinctive blue-white color. Optical brighteners are used in a variety of commercial and industrial products, particularly surfactants. Therefore, if examination of a cotton detector indicated that an optical brightener was present, the charcoal detector was used to confirm recovery of the Tinopal CBS-X tracer dye.

Analysis of Charcoal Detectors

Analysis of charcoal dye detectors requires the use of an elutant to expel the absorbed dye(s) from the charcoal. The elutant solution consists of 5% ammonium hydroxide solution (30% reagent grade) and 95% isopropyl alcohol (70% reagent grade). Approximately 20 grams of charcoal were removed from each fiberglass packet and placed in individual, labeled, 40-ml glass vials.

The charcoal in each vial was submerged in about 20 - 30-ml of elutant solution and eluted for 4-6 hours prior to spectrofluorometric analysis.

To conduct the analysis, a 3-ml aliquot of elutant was removed from a sample vial using a disposable-tipped micropipettor. The aliquot was dispensed into a non-fluorescent optical glass cuvette and placed in a Shimadzu RU-5000 scanning spectrofluorophotometer. Synchronous scanning techniques, as described by Duley (1986)¹, were used to determine the presence or absence of tracer dye.

In a solvent such as water or elutant, molecules of fluorescent dyes are energized by exposure to light of a particular wavelength range (the excitation spectrum) and respond by emitting light at a longer wavelength range (the emission spectrum). The fluorescent properties of dyes used in this investigation in water and elutant are listed in Table 1. The emission spectrum obtained for a particular dye by synchronous scanning is unique and provides a "fingerprint" fluorescent signature that confirms the presence of the dye in the solvent (fig. 1). The characteristics of the emission spectrum for a dye in a particular solvent are determined by synchronous scanning of an elutant sample obtained from charcoal spiked with a dye solution of known concentration (a dye solution standard). Example spectrofluorographs illustrating the emission spectra of Rhodamine WT, Tinopal CBS-X, and Eosine OJ (obtained on charcoal detectors from a field site in Kentucky) are included in Appendix 1.

Table 3. Fluorescent Properties for Commonly-Used Tracer Dyes obtained by Synchronous Scanning with the Shimadzu R5000U Scanning Spectrofluorophotometer

DYE NAME / COLOR INDEX	EXCITATION MAXIMA (nm)		EMISSION MAXIMA (nm)		DETECTION LIMITS*	
	WATER	ELUTANT	WATER	ELUTANT	WATER	ELUTANT
SODIUM FLUORESCIN (C. I. ACID YELLOW 73)	494	499	516	519 ± 2	.05	.01
RHODAMINE WT (C. I. ACID RED 388)	558	554	574	570 ± 1	.05	.15
TINOPAL CBS-X OPTICAL BRIGHTENER	355	—	427	402 ± 2	.1	—
EOSINE OJ (C. I. ACID RED 87)	360	—	—	545 ± 2	—	—

*In parts per billion (ppb). Sources: Duley, J. W., 1986, and N. Crawford (personal communication, 1994).

¹ Duley, J. W., 1986. Water tracing using a scanning spectrofluorometer for detection of fluorescent dyes. In Proceedings of the Environmental Problems in Karst Terranes and their Solutions Conference, October 28-30, 1986, Bowling Green, Kentucky. National Water Well Association (National Ground Water Association), pp. 389-406.

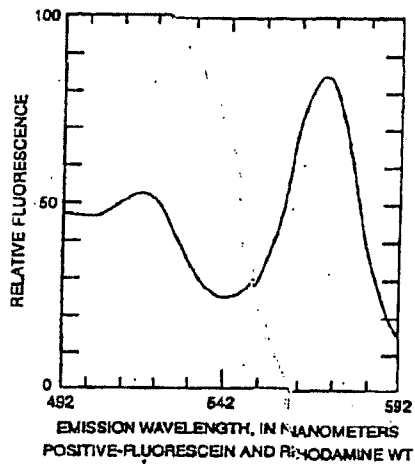
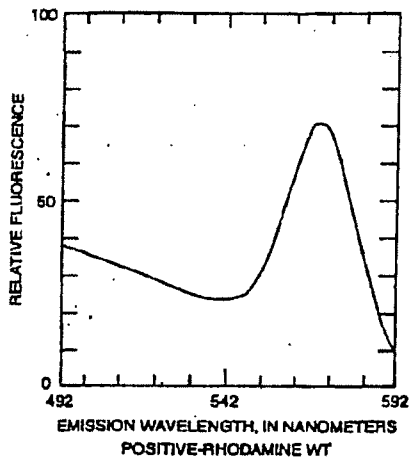
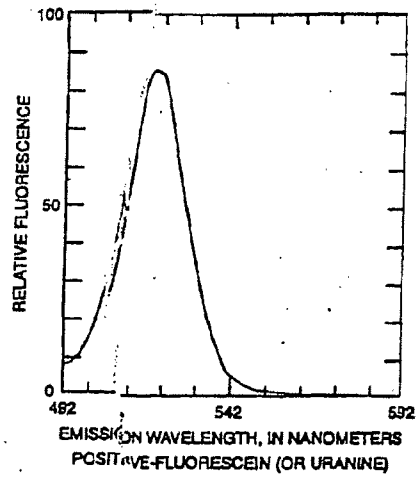
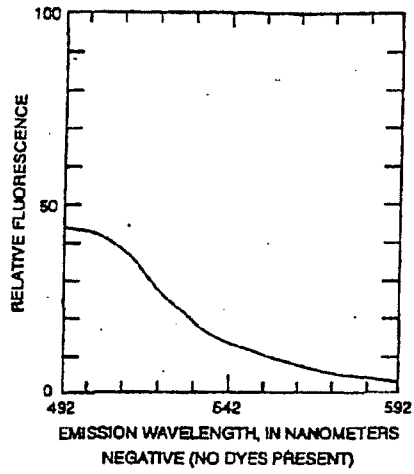


Figure 3. Spectrofluorographs showing characteristic peak emission spectra for selected tracer dyes.

Criteria for Interpretation of Positive Dye Recovery:

A variety of naturally-occurring and man-made solutes that are fluorescent may be present in surface or ground water and absorbed by charcoal dye detectors. If present at sufficiently high concentrations in the elutant, these will contribute an ambient fluorescent signal recorded as "noise" by the scanning spectrofluorophotometer. This background or ambient fluorescence can interfere with the identification of a tracer dye and must be evaluated using "background" dye detectors collected from each selected dye-monitoring site for a time prior to the initiation of the dye-tracer test. The fluorescent signal (emission spectrum) of a tracer dye may be masked by the background fluorescence where the concentration of the dye is relatively low compared to the concentrations of the solutes contributing to the background fluorescence, or where the emission peaks of the tracer dye and ambient fluorescent solute(s) are similar in wavelength.

To objectively distinguish between the fluorescent signal provided by a tracer dye and that of any ambient fluorescent solutes (thus preventing or minimizing the likelihood of recording false positive tracer-test results) a set of conservative analytical criteria are employed to evaluate the results of spectrofluorometric analysis. These criteria are adopted from those used by the Missouri Geological Survey (Jim Vandike, Missouri Geological Survey, written communication, 1994) and Karst Research Institute at Western Kentucky University (Dr. Nicholas Crawford, personal communication, 1994).

Positive detection or recovery of a particular tracer dye is indicated where:

- (1) The emission spectrum obtained is a symmetrical waveform with a peak wavelength characteristic of the tracer dye, as determined by analysis of elutant obtained from a charcoal sample spiked with dye-solution standard (Table 3).
- (2) The fluorescent intensity or dye concentration measured by the spectrofluorophotometer at the peak emission wavelength for the indicated tracer dye is at least 3 times greater than that measured at the detection limit for the dye in the elutant.
- (3) Where background fluorescent noise is low and no fluorescent solute is present in background samples that potentially interferes with the identification of a tracer dye, the fluorescent intensity or dye concentration measured at the peak emission wavelength for the tracer dye must be at least 5 times greater than that measured in all background samples.

If background fluorescent noise is significant, or analysis of background samples indicates the presence of a fluorescent solute that potentially interferes with the identification of tracer dye, the fluorescent intensity or dye concentration measured at the peak emission wavelength for the tracer dye must be at least 10 times greater than that measured in all background samples.

Summary of Analytical Results:

Copies of the log sheets used to record the analysis of all dye detectors collected during the tracer tests are contained in Appendix 1. Results of spectrofluorometric analyses are reported in fluorescent intensity units measured at the peak emission wavelength of the prospective tracer dye. Analytical results are not reported in normal terms of concentration (for example, micrograms per liter or parts per billion) of tracer dye because the fluorescent intensity of the emission peak indicates the concentration of dye in the elutant, not the water the detector was exposed to. Moreover the mass of dye absorbed on passive charcoal detectors is dependent on the concentration of dye in the ground or surface water (which changes with dispersion of the dye cloud), the total time of exposure to dye, and the surface area of charcoal exposed to the dye cloud.

- (1) Tinopal CBS-X was positively recovered on January 14, 1998, on cotton and charcoal detectors in monitoring well Di:F-91 (Ladd #3). Recovery of the tracer dye within 24 hours of injection indicates that the injected dye moved rapidly as a slug through fractures.

Cotton detectors recovered from site #12 (Wetland at sump) on January 14, and February 6, 1998, seemed to exhibit a weak visible fluorescence under ultraviolet light. Subsequent analysis of the charcoal detectors collected from this site on those two dates did not indicate the recovery of Tinopal CBS-X. Optical brighteners are common additives in surfactants, therefore, the weak fluorescence detected at site #12 may be due to other types of optical brighteners in materials buried at the old landfill.

- (2) Rhodamine WT and Eosine OJ tracer dye, injected in wells at the center and southern parts of the old landfill, respectively, were not recovered at any of the dye-monitoring sites. Water samples collected from the two injection sites on April 30, 1998, were visibly discolored with the respective dyes, indicating little or no migration of the two dye slugs more than four months after injection.
- (3) Due to natural attenuation and biologic degradation, concentrations of injected tracer dyes decrease with increasing residence time in the subsurface. Rhodamine WT is the most conservative of the three injected tracer dyes and is the best suited for long-term monitoring. Charcoal detectors were collected from all dye-monitoring sites until September 29, 1998 and analyzed for recovery of Rhodamine WT. No indication of the tracer dye was found in elutant obtained from these samples.

Tinopal CBS-X optical brightener is the least conservative of the three injected tracer dyes and will degrade rapidly (over several weeks) in the subsurface. Use of cotton detectors for recovery of Tinopal CBS-X tracer dye was discontinued after evaluation of the detectors collected on March 20, 1998. Monitoring for the recovery of this tracer dye was continued at site #2 (Sullivan well), #3 (near Sullivan spring), #4 (DK-21 well), and #5 (Sullivan spring), using charcoal detectors collected February 20 - September 29, 1998. No indication of the tracer dye was found in elutant obtained from these samples.

Analysis of elutant from charcoal detectors for the presence of Eosine OJ, was performed on charcoal detectors collected at all sites until March 20, 1998. After this date, monitoring for the recovery of the tracer dye continued at sites #2 (Sullivan well), #3 (near Sullivan spring), #4 (DK-21 well), and #5 (Sullivan spring), using charcoal detectors, until September 29, 1998. No indication of the tracer dye was found in elutant obtained from these samples.

- (4) Samples of cloudy and discolored water collected from the sediment pond on April 30 and June 18, 1998, were analyzed and tested negative for the presence of all three tracer dyes.
- (5) Ambient fluorescence evaluated at all selected dye-monitoring sites prior to injection did not indicate the presence of any fluorescent solutes that would interfere with identification of the three tracer dyes. However, two fluorescent solutes from unknown sources were detected periodically at several sites during the dye-monitoring period for the tracer tests. The detection of these fluorescent solutes required use of the more restrictive analytical evaluation criteria (see #3 above) to assess the results obtained from synchronous scans for Rhodamine WT and Eosine OJ.

The first unknown fluorescent solute exhibited an emission spectrum with a wavelength peak at 519-520 nanometers (nm). This fluorescent signature is similar to that for sodium fluorescein, commonly used as a tracer dye and as coloring agent in various industrial products (particularly antifreeze solutions). This unknown fluorescent solute was frequently recovered on charcoal detectors collected from site #12 (wetland at sump) and #14 (cattails).

The second unknown fluorescent solute exhibited an emission spectrum with a wavelength peak at 576 nanometers (nm). This fluorescent signature is similar to that for Sulforhodamine B dye, sometimes used as a tracer dye and as coloring agent in inks and dyes. This unknown fluorescent solute was recovered on charcoal detectors collected on 1/26/98 from site #2 (Sullivan well), #5 (Sullivan spring), #21 (Donegan spring), #25 (Fielder spring), and #25A (Somersall spring).

To conclude this report, it should be noted that negative tracer recovery does not conclusively prove the lack of a point-to-point hydraulic connection between the dye-injection site and dye-monitoring sites. Negative tracer test results may be obtained where: (1) an insufficient amount of time was allowed for monitoring for dye resurgence, (2) ground-water flow velocities are low and dispersion of dye in the aquifer is high, (3) the concentration of dye in ground water was diluted below its detection limit because of the distance traveled, or the presence of high or flood flow conditions during the test, and (4) the actual dye flowpath(s) and resurgence point(s) were not identified and monitored during the test.

REFERENCES

Duley, J.W., 1986, Water tracing using a scanning spectrofluorometer for detection of fluorescent dyes, *in Proceedings of the Environmental Problems in Karst Terranes and their Solutions Conference*, October 28-30, 1986, Bowling Green, Kentucky: National Water Well Association (National Ground Water Association), p. 389-406.

Ladd, D.E., 1996, Construction, lithologic, and water-level data for wells near the Dickson County landfill, Dickson County, Tennessee, 1995: U.S. Geological Survey Open File Report 96-229, 16 p.

APPENDIX 1: RESULTS OF ANALYSIS OF DYE DETECTORS,
DICKSON COUNTY LANDFILL INVESTIGATION

A1: RESULTS OF ANALYSIS FOR TRACER TEST 1 (EOSINE OJ)

RECORD OF DYE-TRACER TEST RESULTS

Tracer Test No. I Location DICKSON COUNTY, TN LANDFILL

Injection Date 1/13/98 Tracing Agent EOSINE OJ

Date of Collection	12/9/97	12/16	1/14/98	1/16	1/21	1/26	1/30	2/6	2/11	2/20
Time Since Dye Injection										

ID	Location of Dye Detector	Back-ground	Results (Use qualitative codes below, or enter fluorometer readings)								
1	BAPTISM FORK	.H	φ	6.1	.81	2.8	4.3	.92	4.5	2.9	NR
2	SULLIVAN WELL	NR	NR	.57	.65	.35	.57	.57	.47	.61	.32
3	NEAR SULLIVAN SPRING	φ	.27	3.5	.63	.80	.57	.73	1.6	.67	.89
4	DK-21 WELL	.H	1.7	9.8	.93	NR	14.0 ²	8.2	10.6 ²	6.4	4.4
4A	AT LAKE BELOW DAM	NR	NR	8.8	.86	8.8	10.0	5.6	5.8	5.7	5.3
5	SULLIVAN SPRING	φ	φ	2.4	.61	2.0	1.3	.83	1.3	1.7	.92
6	F-86 WELL	-	-	-	-	-	-	-	-	-	-
7	ROADSIDE POND	φ	.16	3.1	.60	NR	1.6	1.2	1.6	.93	1.2
8	F-91 WELL	NR	φ	1.3	.55	NR	.44	1.5	.44	.64	.32
9	WET DEPRESSION	φ	.12	6.6	.63	NR	1.8	1.7	1.8	1.4	2.1
10	COUNTY LANDFILL	-	-	-	-	-	-	-	-	-	-
11	ARMSTRONG WELL	NR	φ	.74	.63	NR	.32	.80	.44	.51	.38
12	WETLAND AT SUMP	4.4 ²	5.0 ²	61.1 ²	.80	NR	50 ²	14.3 ²	34.5 ²	29.1 ²	NR
13	CITY LANDFILL	-	-	-	-	-	-	-	-	-	-
14	CATTAILS	6.5 ²	10.4 ²	95.4 ²	1.9 ²	NR	54.3 ²	60 ²	64.1 ²	47.6 ²	39.6 ²

All Fluorometer Readings in: Unit Fluorescent Intensity Concentration (ppb)

- | | |
|-------------------------------------|--|
| N Negative (No Dye Detected) | B- No Background |
| WP Weakly Positive Dye Detection | B+ Significant (problematic) Background |
| P Positive Dye Detection | NR Dye Detector Not Recovered (high water, lost, etc.) |
| EP Extremely Positive Dye Detection | - Detector not installed |

Remarks/ Interpretation

NO RECOVERY OF EOSINE OJ TRACER DYE
1 HIGH LEVEL OF AMBIENT FLUORESCENCE IN SAMPLE - NO WAVEFORM PEAK - NOT CHARACTERISTIC OF ANY TRACER DYE
2 AMBIENT FLUORESCENCE DUE TO WAVEFORM WITH EMISSION PEAK AT 519-520 nm - POSSIBLY SODIUM FLUORESCIN - SPECTROFLUOROGRAPH ATTACHED

RECORD OF DYE-TRACER TEST RESULTS

Tracer Test No. 1 Location DICKSON COUNTY, TN LANDFILL

Injection Date 1/13/98 Tracing Agent EOSINE OJ

Date of Collection	12/9/97	12/16	1/14/98	1/16	1/21	1/26	1/30	2/6	2/11	2/20
Time Since Dye Injection										

ID	Location of Dye Detector	Back-ground	Results (Use qualitative codes below, or enter fluorometer readings)								
14A	HUMANE SOCIETY	14.2	3.2	NL	.63	NL	2.6	2.2	1.9	1.4	1.3
15	DK-9 WELL	NL	∅	.32	.54	NL	.32	.51	.30	.38	.32
16	SEEP UNDER TREE	1.4	2.1	13.5 ^Z	.90	NL	10.3 ^Z	1.5	11.2 ^Z	12.2 ^Z	7.5
17	PAYNE SPRING	NL	2.9	20.2 ^Z	1.0	17.1 ^Z	15 ^Z	10.7 ^Z	NL	8.2	6.2
18	WORLEY FURN. BR (MOUTH)	.81	.92	6.8	2.2	10.8 ^Z	8.8	8.4	6.9	3.6	4.3
19	TICE SPRING	.80	.96	6.8	1.1	NL	6.5	5.9	6.5	5.4	4.7
20	DONEGAN SP. #2	.96	1.5	6.3	1.6	NL	7.2	3.4	4.3	3.1	2.9
21	DONEGAN SPRING	NL	.82	2.8	.64	3.8	2.0	1.3	1.4	1.7	2.6
22	BAKER BR.	1.4	1.3	6.8	1.5	10.4 ^Z	7.6	6.1	7.8	6.8	4.9
23	REDOEN SP.	1.9	2.9	9.4 ^Z	2.2	9.8 ^Z	8.6	7.0	6.7	6.3	4.0
24	BRUCE SP.	NL	.52	1.7	.73	.96	1.3	1.1	1.2	1.2	.96
25	FIELDER SP.	NL	.56	2.2	.72	.83	1.5	1.2	1.3	.72	1.2
25A	SOMERALL SPRING	NL	.37	.44	.46	.44	.44	.71	.38	.48	.44

All Fluorometer Readings in: Unit Fluorescent Intensity Concentration (ppb)

- | | |
|-------------------------------------|--|
| N Negative (No Dye Detected) | B- No Background |
| WP Weakly Positive Dye Detection | B+ Significant (problematic) Background |
| P Positive Dye Detection | NR Dye Detector Not Recovered (high water, lost, etc.) |
| EP Extremely Positive Dye Detection | - Detector not installed |

Remarks/interpretation

RECORD OF DYE-TRACER TEST RESULTS

Tracer Test No. 1 Location Dickson County, TN LANDFILL

Injection Date 1/15/98 Tracing Agent EOSINE OJ

Date of Collection	2/27/98	3/6	3/20	4/3	4/30	5/18	6/16	7/8	7/29	8/19
Time Since Dye Injection										

ID	Location of Dye Detector	Back-ground	Results (Use qualitative codes below, or enter fluorometer readings)								
			2/27/98	3/6	3/20	4/3	4/30	5/18	6/16	7/8	7/29
1	BAPTISM FORK	2.9	2.5	3.1	NA	NA	NR	NA	NR	NA	NA
2	SULLIVAN WELL	1.6	.28	.38	.76	.55	.59	1.4	.62	.64	2.6
3	NEAR SULLIVAN SPRING	1.4	.41	.48	.78	.76	.89	1.9	.63	.73	2.6
4	DK-21 WELL	3.5	3.5	2.9	4.5	2.8	2.6	3.2	.92	.91	3.1
A	AT LAKE BELOW DAM		.86	2.1	NA	NA	NA	NA	NA	NA	NA
5	SULLIVAN SPRING	1.4	.57	.76	1.2	.70	1.2	1.1	0	.97	2.6
6	F86 WELL	-	-	-	-	-	-	-	-	-	-
7	ROADSIDE POND	1.1	.52	.99	NA	NA	NA	NA	NA	NR	NA
8	F-91 WELL	1.4	.32	.99	NA	NA	NA	NA	NA	NA	NA
9	WET DEPRESSION	1.8	.70	1.4	NA	NA	NA	NA	NA	NA	NA
10	COUNTY LANDFILL	-	-	-	-	-	-	-	-	-	-
11	ARMSTRONG WELL	1.3	.28	.44	NA	NA	NR	NR	NA	NA	NA
12	WETLAND AT SUMP	4.1	5.3	6.8	NA	NA	NA	NR	NA	NA	NA
13	CITY LANDFILL	-	-	-	-	-	-	-	-	-	-
14	CATTAILS	2.6 ²	6.1	8.4 ²	NA	NA	NA	NA	NA	NA	NA

All Fluorometer Readings in: Unit Fluorescent Intensity Concentration (ppb)

- N Negative (No Dye Detected)
- WP Weakly Positive Dye Detection
- P Positive Dye Detection
- EP Extremely Positive Dye Detection
- B- No Background
- B+ Significant (problematic) Background
- NR Dye Detector Not Recovered (high water, lost, etc.)
- Detector not installed

marks/ interpretation

RECORD OF DYE-TRACER TEST RESULTS

Tracer Test No. 1 Location DICKSON COUNTY, TN LANDFILL

Injection Date 1/13/98 Tracing Agent EOSINE OJ

Date of Collection	2/27/98	3/6	3/20	4/3	4/30	5/18	6/16	7/8	7/29	8/19
Time Since Dye Injection										

ID	Location of Dye Detector	Back-ground	Results (Use qualitative codes below, or enter fluorometer readings)								
14A	HUMANE SOCIETY	1.9	1.1	1.6	NL	NA	NA	NA	NA	NL	NA
15	DK-9 WELL	1.5	.28	NL	NA	NL	NA	NA	NA	NA	NA
16	SEEP UNDER TREE	2.6	4.8	5.6	NA	NA	NA	NA	NA	NA	NA
17	PAYNE SPRING	3.3	3.8	4.3	NL	NL	NA	NA	-	-	-
18	WORLEY FURN. BR. (MOUTH)	2.4	3.0	4.3	NA	NA	NA	NL	NA	NA	NA
19	TICE SPRING	2.0	1.7	3.1	NA	NA	NA	NL	-	-	-
20	DONEGAN SP. #2	1.6	1.7	1.3	NA	NA	NA	NA	-	-	-
21	DONEGAN SPRING	1.8	.83	.89	NA	NL	NA	NA	-	-	-
22	BAKER BR.	2.8	4.9	3.9	NA	NA	NA	NA	NA	NA	NA
23	REDDEN SP.	2.6	3.6	3.8	NA	NL	NA	NA	-	-	-
24	BRUCE SP.	1.3	.83	.57	NA	NL	NA	NA	-	-	-
25	FIELDER SP.	1.3	.83	.89	NA	NL	NA	NA	-	-	-
25A	SOMERALL SPRING	1.3	.32	1.44	NA	NL	NA	NA	-	-	-

All Fluorometer Readings in: Unit Fluorescent Intensity Concentration (ppb)

- N Negative (No Dye Detected)
- WP Weakly Positive Dye Detection
- P Positive Dye Detection
- EP Extremely Positive Dye Detection
- B- No Background
- B+ Significant (problematic) Background
- NR Dye Detector Not Recovered (high water, lost, etc.)
- Detector not installed

marks/ interpretation

RECORD OF DYE-TRACER TEST RESULTS

Tracer Test No. 1 Location DICKSON COUNTY, TN LANDFILL

Injection Date 1/13/98 Tracing Agent EOSNE OJ

Date of Collection	9/10/98	9/29							
Time Since Dye Injection									

ID	Location of Dye Detector	Back-ground	Results (Use qualitative codes below, or enter fluorometer readings)						
			9/10/98	9/29					
1	BAPTISM FORK	NA	NA						
2	SULLIVAN WELL	3.6	2.2						
3	NEAR SULLIVAN SPRING	2.5	2.0						
4	DK-21 WELL	3.0	3.4						
A	AT LAKE BELOW DAM	NA	NA						
5	SULLIVAN SPRING	2.0	1.7						
6	F-86 WELL	-	-						
7	ROADSIDE POND	NA	-						
8	F-91 WELL	NA	-						
9	UGT DEPRESSION	NA	-						
10	COUNTY LANDFILL	-	-						
11	ARMSTRONG WELL	NA	NA						
12	WETLAND AT SUMP	NA	NA						
13	CITY LANDFILL	-	-						
14	CATTAILS	NA	NA						

All Fluorometer Readings In: Unit Fluorescent Intensity Concentration (ppb)

- | | |
|-------------------------------------|--|
| N Negative (No Dye Detected) | B- No Background |
| WP Weakly Positive Dye Detection | B+ Significant (problematic) Background |
| P Positive Dye Detection | NR Dye Detector Not Recovered (high water, lost, etc.) |
| EP Extremely Positive Dye Detection | - Detector not installed |

Remarks/ Interpretation

RECORD OF DYE-TRACER TEST RESULTS

Tracer Test No. 1 Location DICKSON COUNTY, TN LANDFILL

Injection Date 1/13/98 Tracing Agent EOSINE D

Date of Collection	9/10/98	9/29								
Time Since Dye Injection										

ID	Location of Dye Detector	Back-ground		Results (Use qualitative codes below, or enter fluorometer readings)									
14A	HUMANE SOCIETY	-	-										
15	DK-9 WELL	NA	NA										
16	SEEP UNDER TREE	NA	-										
17	PAYNE SPRING	-	-										
18	WORLEY FURN. BR. (MOUTH)	NA	NA										
19	TICE SPRING	-	-										
20	DONEGAN SP. #2	-	-										
21	DONEGAN SPRING	-	-										
22	BAKER BR.	NA	NA										
23	REDDEN SP.	-	-										
24	BRUCE SP.	-	-										
25	FIELDER SP.	-	-										
25A	SOMERALL SPRING	-	-										

All Fluorometer Readings in: Unit Fluorescent Intensity Concentration (ppb)

- N Negative (No Dye Detected)
- WP Weakly Positive Dye Detection
- P Positive Dye Detection
- EP Extremely Positive Dye Detection
- B- No Background
- B+ Significant (problematic) Background
- NR Dye Detector Not Recovered (high water, lost, etc.)
- Detector not installed

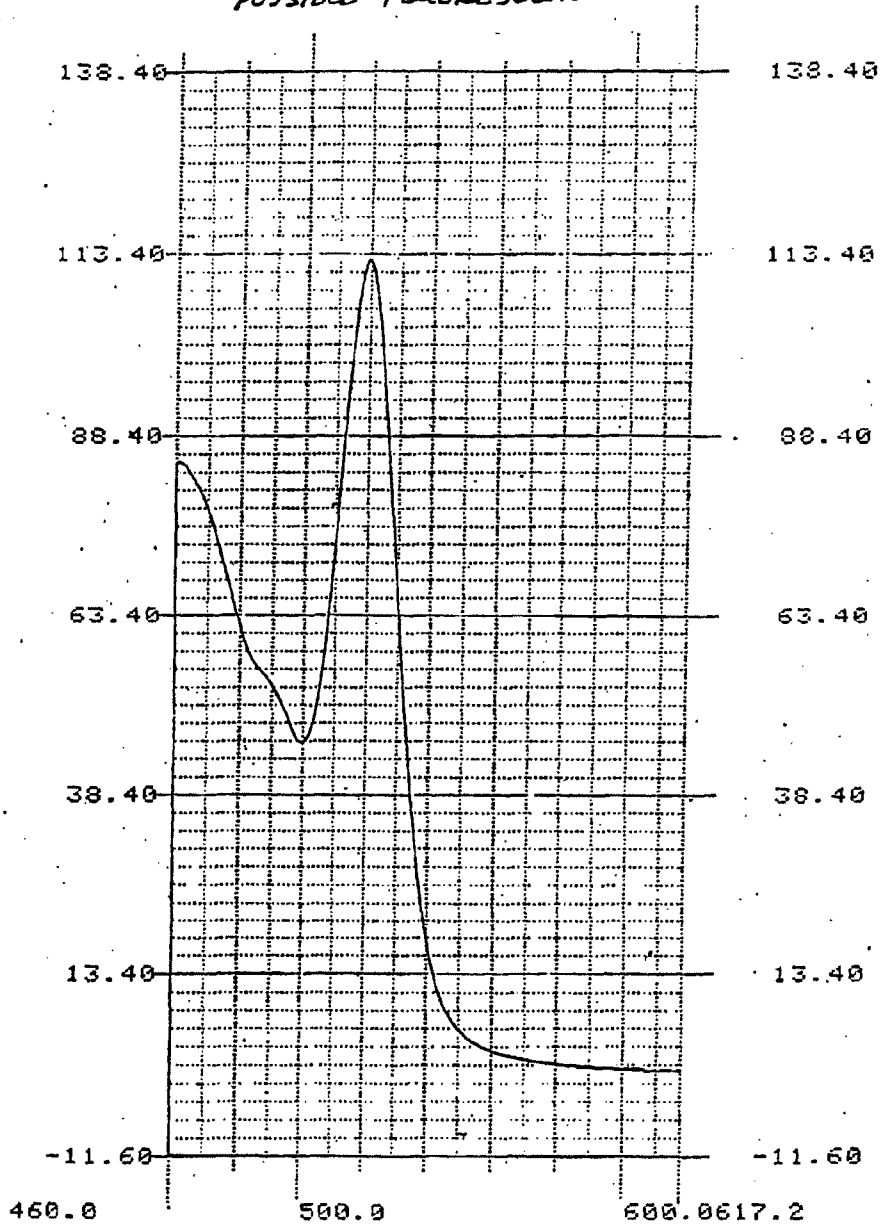
Remarks/ Interpretation

TN12 1/24/98 (WETLAND)

AI-7

PEAK @ 520nm, F.I. = 112

POSSIBLE FLUORESCEN

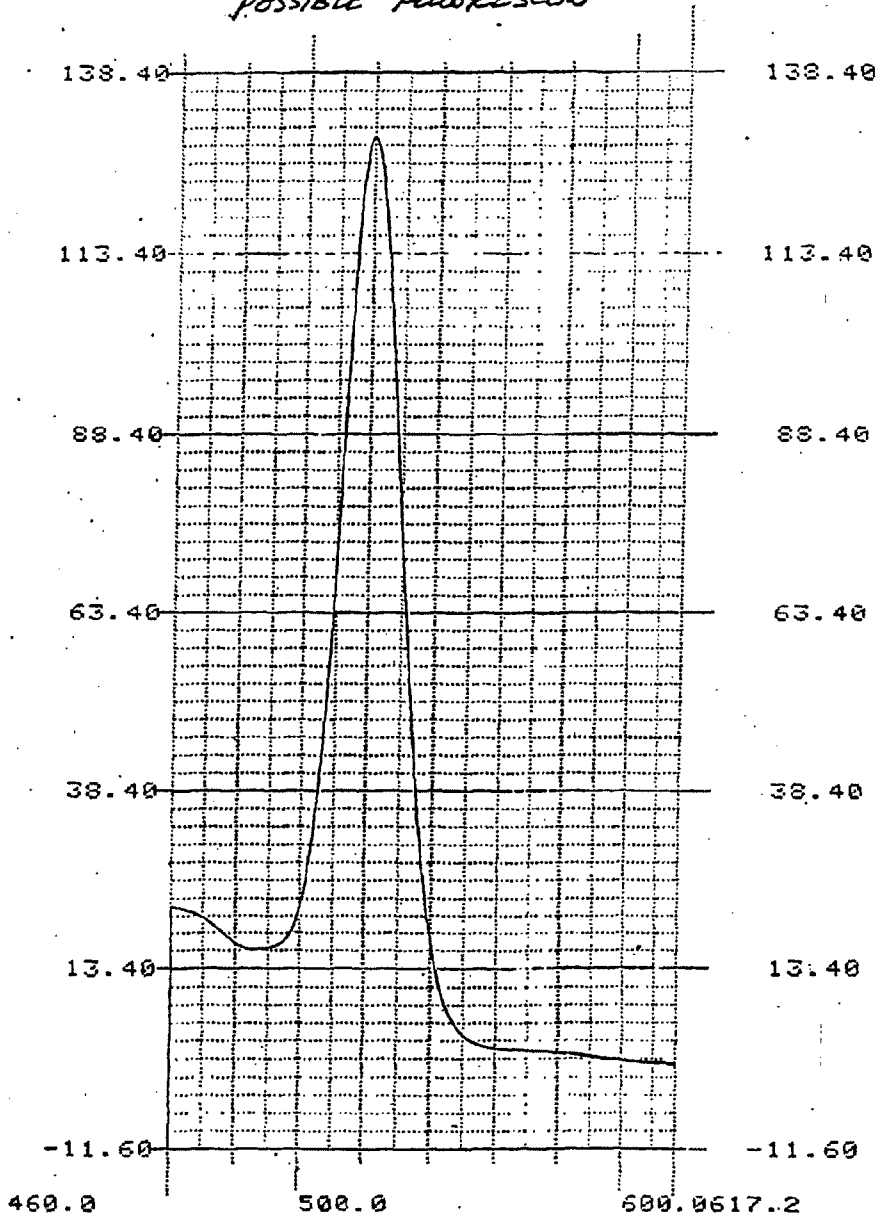


TN 14 1/26/98 (CATTAILS)

AI-8

PEAK @ 519.6 nm, F.I. = 129

POSSIBLE FLUORESCEN



A2: RESULTS OF ANALYSIS FOR TRACER TEST 2 (RHODAMINE WT).

RECORD OF DYE-TRACER TEST RESULTS

Tracer Test No. 2 Location DICKSON COUNTY, TN LANDFILL

Injection Date 1/13/98 Tracing Agent RHODAMINE WT

Date of Collection	12/9/97	12/16	1/14/98	1/16	1/21	1/24	1/30	2/6	2/11	2/20
Time-Since Dye Injection										

ID	Location of Dye Detector	Back-ground	Results (Use qualitative codes below, or enter fluorometer readings)								
1	BAPTISM FORK	.96	.64	2.2	2.6	1.1	1.7	1.3	1.6	1.1	NR
2	SULLIVAN WELL	NR	NR	2.2	2.3	1.1	5.5 ²	1.6	1.6 ²	1.6	2.3
3	NEAR SULLIVAN SPRING	.27	.56	2.1	2.9	1.7	2.1	1.8	.83	1.7	2.1
4	DK-21 WELL	.68	.60	1.9	2.7	NR	2.1	1.7	2.0	1.9	1.9
4A	AT LAKE BELOW DAM	NR	NR	1.8	2.7	1.7	1.8	1.5	1.7	1.6	1.8
5	SULLIVAN SPRING	.67	.73	2.2	2.1	1.8	6.8 ²	1.3	1.1	1.4	2.0
6	F-86 WELL	-	-	-	-	-	-	-	-	-	-
7	ROADSIDE POND	.83	.67	2.1	2.9	NR	1.8	1.6	.96	1.5	2.6
8	F-91 WELL	NR	.86	3.5	2.8	NR	3.5	1.6	1.2	1.3	2.9
9	UGT DEPRESSION	.64	.28	1.8	3.0	NR	.96	1.3	1.3	1.3	2.3
10	COUNTY LANDFILL	-	-	-	-	-	-	-	-	-	-
11	ARMSTRONG WELL	NR	.54	3.4	.30	NR	1.2	1.4	.96	1.2	2.2
12	WETLAND AT SWAMP	.87	.99	1.7	2.7	NR	.70	1.7	2.2	1.7	NR
13	CITY LANDFILL	-	-	-	-	-	-	-	-	-	-
14	CATTAILS	1.1	.80	1.7	2.1	NR	2.0	2.0	1.7	2.0	1.7

All Fluorometer Readings In: Unit Fluorescent Intensity Concentration (ppb)

- N Negative (No Dye Detected)
- WP Weakly Positive Dye Detection
- P Positive Dye Detection
- EP Extremely Positive Dye Detection
- B- No Background
- B+ Significant (problematic) Background
- NR Dye Detector Not Recovered (high water, lost, etc.)
- Detector not installed

Remarks/ Interpretation

NO RECOVERY OF RHODAMINE WT TRACER DYE
 I - UNKNOWN FLUORESCENT SOLUTE WITH EMISSION PEAK AT 576 NM ~
 SIMILAR TO SULFORHODAMINE B DYE, NOT RHODAMINE WT

RECORD OF DYE-TRACER TEST RESULTS

Tracer Test No. 2 Location DICKSON COUNTY, TN LANDFILL

Injection Date 1/13/98 Tracing Agent RHODAMINE WT

Date of Collection	12/9/97	12/16	1/14/98	1/16	1/21	1/26	1/30	2/6	2/11	2/20
Time Since Dye Injection										

ID	Location of Dye Detector	Back-ground	Results (Use qualitative codes below, or enter fluorometer readings)								
14A	HUMANE SOCIETY	.80	.21	NK	.39	NK	2.0	2.1	1.2	1.9	2.4
15	DK-9 WELL	NK	∅	1.7	2.4	NK	1.7	1.4	1.1	1.8	1.8
16	SEEP UNDER TREE	.35	.62	2.0	2.4	NK	1.5	1.3	1.5	2.0	2.0
17	PAYNE SPRING	NK	.83	2.8	2.5	.70	2.0	1.8	NK	1.8	2.2
18	WORLEY FURN. BR (MOUTH)	.10	.19	1.2	1.5	1.7	1.7	1.7	1.4	1.8	2.0
19	TICE SPRING	.06	.09	1.2	2.2	NK	1.5	1.4	1.5	1.7	1.7
20	DONEGAN SP. #2	.12	.44	1.2	1.9	NK	1.5	1.7	1.1	1.4	1.5
21	DONEGAN SPRING	NK	.08	.70	2.4	1.1	2.5 ²	1.8	1.2	1.5	1.5
22	BAKER BR.	.44	.32	.70	1.7	1.5	1.6	1.7	1.7	1.8	1.6
23	REDDEN SP.	.57	1.0	1.2	1.7	1.6	1.5	1.6	1.7	1.8	1.7
24	BRUCE SP.	NK	.10	.70	2.7	.70	2.0	1.4	1.0	1.3	1.8
25	FIELDER SP.	NK	∅	.20	2.5	.96	4.9 ²	1.3	1.0	1.3	1.7
25A	SOMERALL SPRING	NK	∅	.60	2.2	1.3	1.8 ²	1.2	1.0	1.3	2.9

All Fluorometer Readings in: Unit Fluorescent Intensity Concentration (ppb)

- N Negative (No Dye Detected)
- WP Weakly Positive Dye Detection
- P Positive Dye Detection
- EP Extremely Positive Dye Detection
- B- No Background
- B+ Significant (problematic) Background
- NR Dye Detector Not Recovered (high water, lost, etc.)
- Detector not installed

marks/
interpretation

RECORD OF DYE-TRACER TEST RESULTS

Tracer Test No. 2 Location Dickson County, TN LANDFILL

Injection Date 1/15/98 Tracing Agent MHODAMINE WT

Date of Collection	2/27/98	3/6	3/20	4/3	4/30	5/18	6/16	7/8	7/29	8/19
Time Since Dye Injection										

ID	Location of Dye Detector	Back-ground	Results (Use qualitative codes below, or enter fluorometer readings)								
1	BAPTISM FORK	1.2	1.3	1.6	1.5	NR	1.6	NR	1.9	1.7	1.7
2	SULLIVAN WELL	1.5	1.9	1.9	2.1	2.1	2.0	1.3	1.9	1.9	2.0
3	NEAR SULLIVAN SPRING	1.3	2.4	1.7	1.4	1.8	1.7	1.1	2.0	1.8	1.8
4	DK-21 WELL	1.2	1.1	1.8	1.6	1.6	1.6	1.3	1.9	1.8	1.5
A	AT LAKE BELOW DAM	NR	1.5	1.7	1.6	1.6	1.5	1.6	1.6	1.6	1.6
5	SULLIVAN SPRING	1.2	1.2	1.9	1.4	1.7	1.5	1.2	1.9	1.8	1.6
6	F-86 WELL	-	-	-	-	-	-	-	-	-	-
7	ROADSIDE POND	.89	1.3	1.8	1.5	1.6	1.2	1.2	2.0	NR	1.7
8	F-91 WELL	1.7	1.5	1.8	1.9	2.1	1.4	1.3	1.8	1.9	2.0
9	WGT DEPRESSION	1.5	1.3	1.5	1.7	1.7	1.1	1.1	1.2	2.2	1.3
10	COUNTY LANDFILL	-	-	-	-	-	-	-	-	-	-
11	ARMSTRONG WELL	1.2	.96	1.5	1.6	2.0	NR	NR	1.3	2.4	1.9
12	WETLAND AT SUMP	1.0	1.5	1.5	1.8	1.7	1.6	NR	3.5	2.0	2.0
13	CITY LANDFILL	-	-	-	-	-	-	-	-	-	-
14	CATTAILS	1.2	1.5	1.8	2.0	1.8	1.5	1.5	1.9	2.4	2.5

All Fluorometer Readings in: Unit Fluorescent Intensity Concentration (ppb)

- N Negative (No Dye Detected)
- WP Weakly Positive Dye Detection
- P Positive Dye Detection
- EP Extremely Positive Dye Detection
- B- No Background
- B+ Significant (problematic) Background
- NR Dye Detector Not Recovered (high water, lost, etc.)
- Detector not Installed

Remarks/ Interpretation

RECORD OF DYE-TRACER TEST RESULTS

Tracer Test No. 2 Location DICKSON COUNTY, TN LANDFILL

Injection Date 1/13/98 Tracing Agent RHODAMINE WT

Date of Collection	2/27/98	3/6	3/20	4/3	4/30	5/18	6/16	7/8	7/29	8/19
Time Since Dye Injection										

ID	Location of Dye Detector	Back-ground	Results (Use qualitative codes below, or enter fluorometer readings)								
14A	HUMANE SOCIETY	1.7	1.3	1.8	NL	2.1	1.6	1.5	1.3	NL	1.7
15	DK-9 WELL	1.5	1.1	NL	1.6	NL	1.8	1.1	1.5	1.9	1.7
16	SEEP UNDER TREE	1.4	1.5	1.6	1.8	1.6	1.5	1.5	1.4	1.6	1.7
17	RAYNE SPRING	1.1	1.4	1.7	NL	NL	1.3	1.5	-	-	-
18	WORLEY FARM BR (MOUTH)	1.1	1.3	1.6	2.0	1.7	1.3	NL	2.7	1.7	1.5
19	TICE SPRING	.96	1.1	1.4	1.7	1.7	1.2	NL	-	-	-
20	DONEGAN SP. #2	.76	1.2	1.3	1.7	1.5	1.1	1.1	-	-	-
21	DONEGAN SPRING	1.2	1.3	1.4	1.6	NL	1.1	1.3	-	-	-
22	BAXER BR.	1.2	1.5	1.6	1.5	1.6	1.3	1.7	1.5	1.7	1.6
23	REDDEN SP.	1.2	1.3	1.6	1.7	NL	1.3	1.5	-	-	-
24	BRUCE SP.	.97	1.2	1.5	1.4	NL	.83	1.0	-	-	-
25	FIELDER SP.	1.0	1.0	1.1	1.5	NL	.96	.96	-	-	-
25A	SOMERALL SPRING	1.3	.90	1.7	1.7	NL	1.5	1.0	-	-	-

All Fluorometer Readings in Unit Fluorescent Intensity Concentration (ppb)

- N Negative (No Dye Detected)
- WP Weakly Positive Dye Detection
- P Positive Dye Detection
- EP Extremely Positive Dye Detection
- B- No Background
- B+ Significant (problematic) Background
- NL Dye Detector Not Recovered (high water, lost, etc.)
- Detector not installed

Remarks/ Interpretation

RECORD OF DYE-TRACER TEST RESULTS

Tracer Test No. 2 Location DICKSON COUNTY, TN LANDFILL

Injection Date 1/13/98 Tracing Agent RHODAMINE WT

Date of Collection	9/10/98	9/29							
Time Since Dye Injection									

ID	Location of Dye Detector	Back-ground	Results						
			(Use qualitative codes below, or enter fluorometer readings)						
1	BAPTISM FORK	1.7	1.6						
2	SULLIVAN WELL	1.8	1.5						
3	NEAR SULLIVAN SPRING	1.7	1.4						
4	DK-21 WELL	2.0	2.0						
4A	AT LAKE BELOW DAM	1.5	1.5						
5	SULLIVAN SPRING	1.7	1.4						
6	F-86 WELL	-	-						
7	RODOLPH POND	1.7	-						
8	F-91 WELL	1.9	-						
9	WET DEPRESSION	1.5	-						
10	COUNTY LANDFILL	-	-						
11	ARMSTRONG WELL	2.0	1.7						
12	WETLAND AT SLUMP	2.9	2.4						
13	CITY LANDFILL	-	-						
14	CATTAILS	5.2	1.6						

All Fluorometer Readings in: Unit Fluorescent Intensity Concentration (ppb)

- N Negative (No Dye Detected)
- WP Weakly Positive Dye Detection
- P Positive Dye Detection
- EP Extremely Positive Dye Detection
- B- No Background
- B+ Significant (problematic) Background
- NR Dye Detector Not Recovered (high water, lost, etc.)
- Detector not installed

Remarks/ Interpretation

RECORD OF DYE-TRACER TEST RESULTS

Tracer Test No. 2 Location DICKSON COUNTY, TN LANDFILL

Injection Date 1/13/98 Tracing Agent RHODAMINE WT

Date of Collection	9/10/98	9/29								
Time Since Dye Injection										

ID	Location of Dye Detector	Back-ground		Results (Use qualitative codes below, or enter fluorometer readings)									
14A	HUMANE SOCIETY	—	—										
15	DK-9 WELL	1.2	5.2										
16	SEEP UNDER TREE	1.5	—										
17	PAYNE SPRING	—	—										
18	WORLEY FURN. BR. (MOUTH)	1.6	1.5										
19	TICE SPRING	—	—										
20	DONEGAN SP. #2	—	—										
21	DONEGAN SPRING	—	—										
22	BAKER BR.	1.7	1.4										
23	KEDDEN SP.	—	—										
24	BRUCE SP.	—	—										
25	FIELDER SP.	—	—										
25A	SOMERALL SPRING	—	—										

All Fluorometer Readings in: Unit-Fluorescent Intensity Concentration (ppb)

- N Negative (No Dye Detected)
- WP Weakly Positive Dye Detection
- P Positive Dye Detection
- EP Extremely Positive Dye Detection
- B- No Background
- B+ Significant (problematic) Background
- NR Dye Detector Not Recovered (high water, lost, etc.)
- Detector not installed

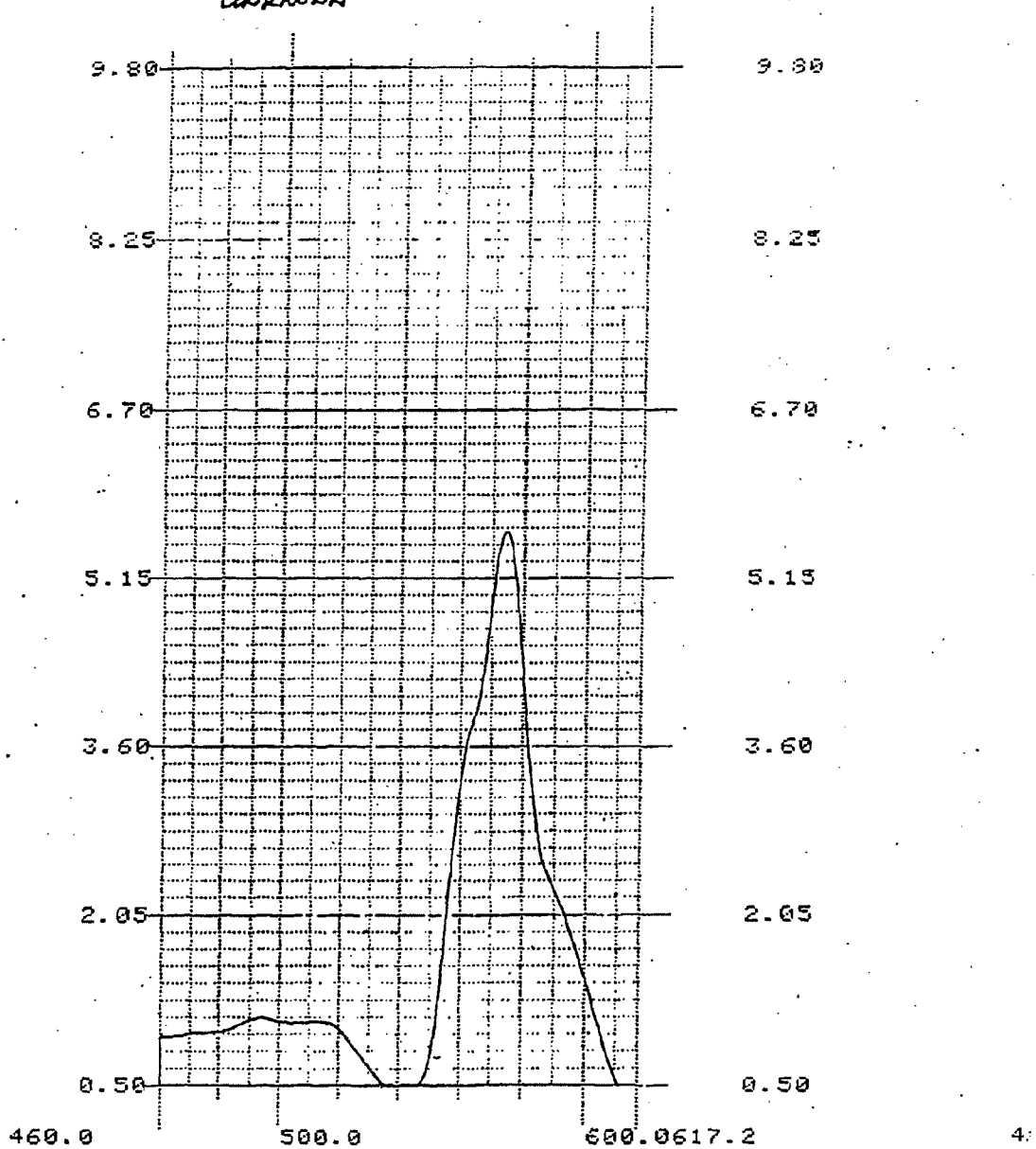
Remarks/ Interpretation

TN 2 1/26/98 (SUNNYVALE WEL)

PAGE A2-7

PEAK @ 576 nm, F.I. = 5.6

UNKNOWN

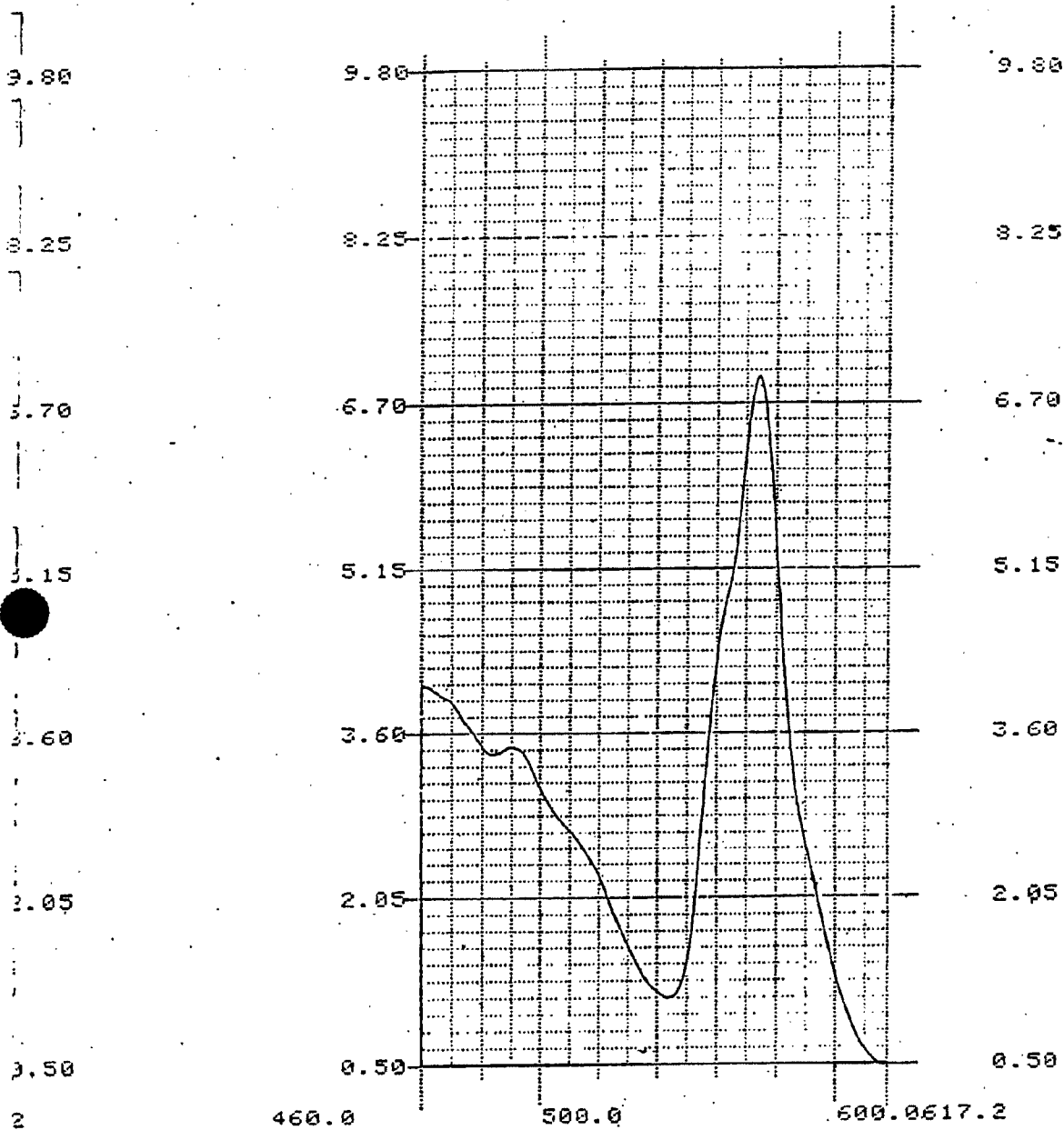


TN 5 1/26/98 (SULLIVAN SPRING)

A2-8

PEAK @ 576 nm, F.I. = 6.8

UNKNOWN

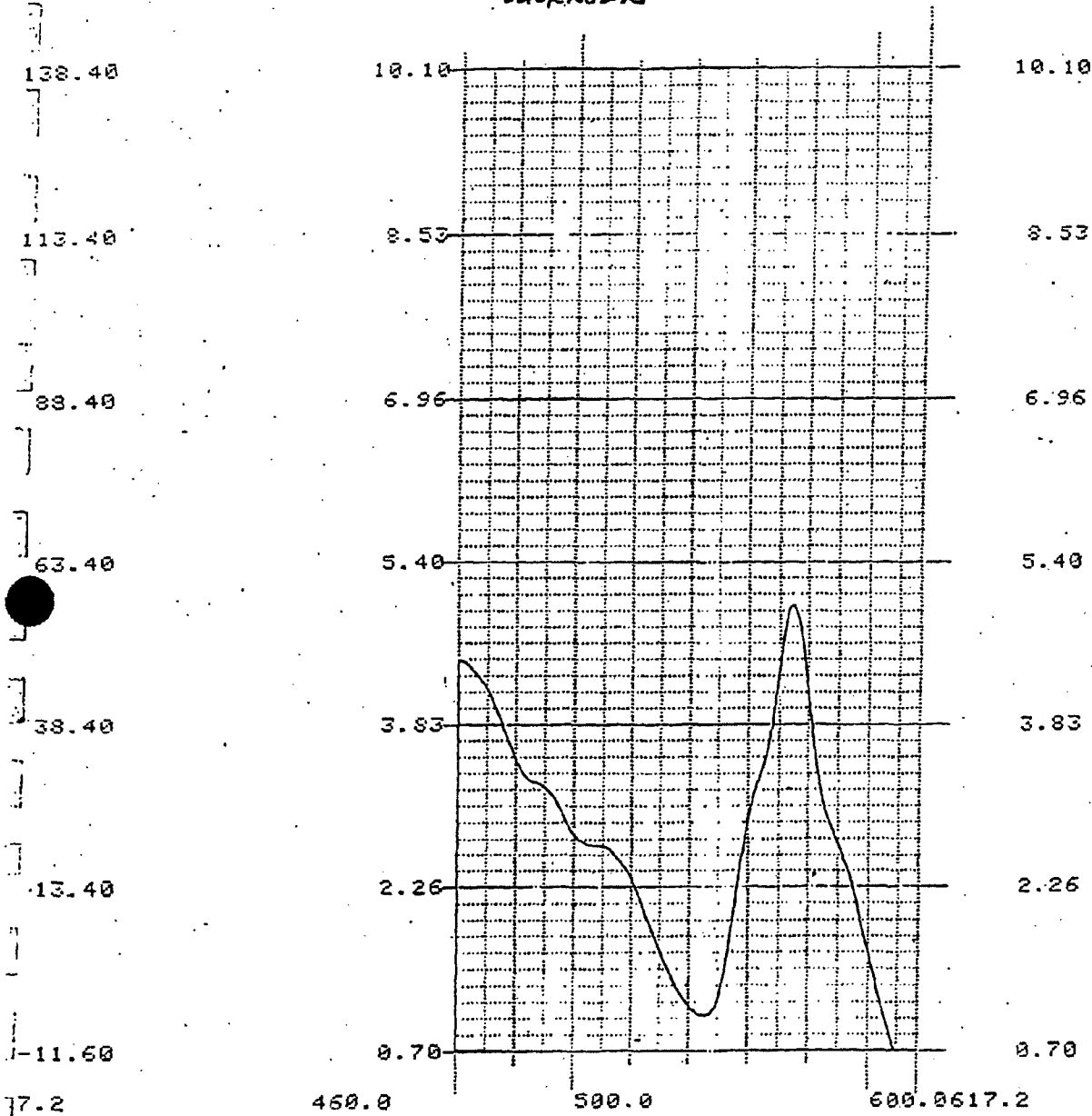


TN 25 1/26/98 (FIELDER SPRING)

A2-9

PEAK @ 576 nm, F.I. = 4.9

UNKNOWN

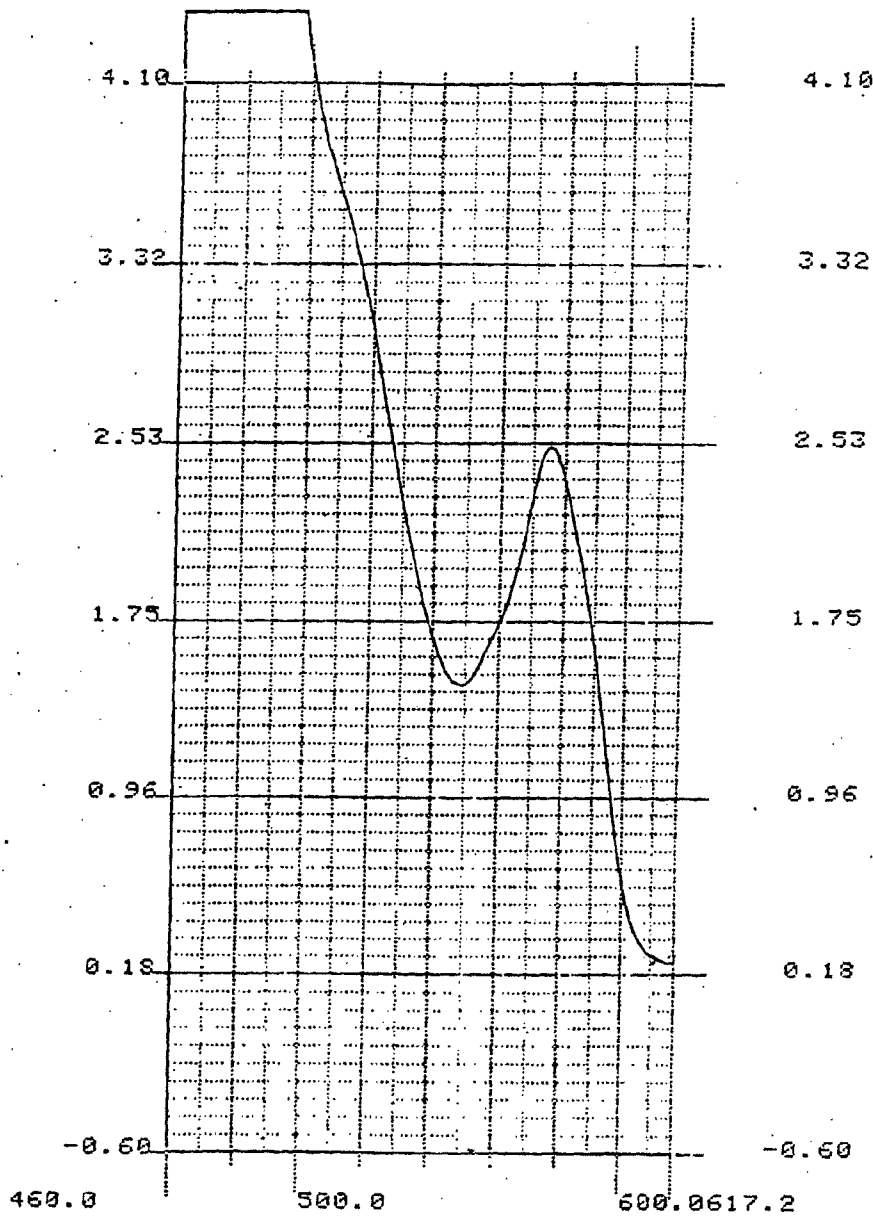


#21 1/26/98 DONEGAN ST

A2-10

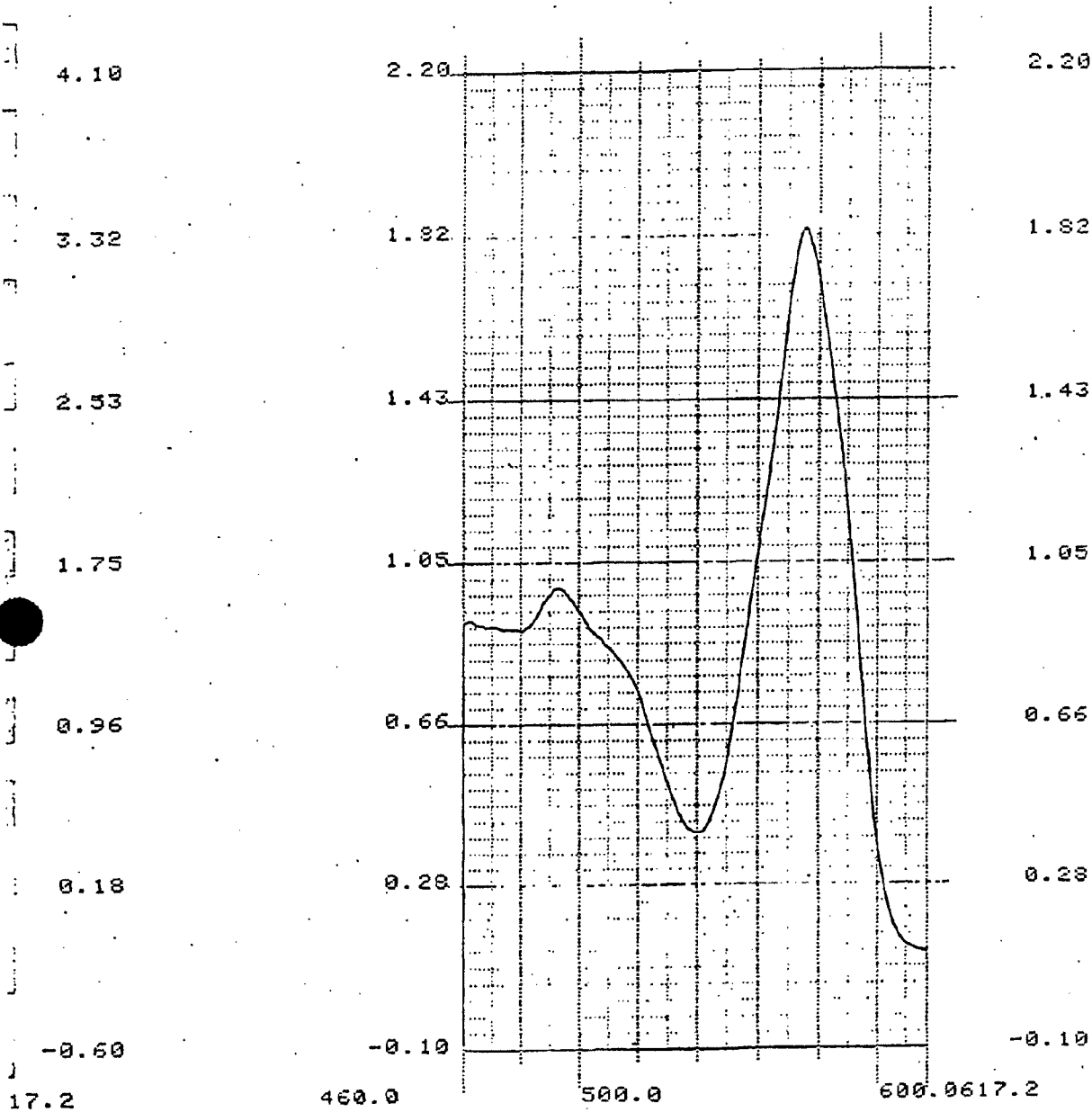
F.I. = 2.5 @ 576 nm

UNKNOWN



TN #25A 1/26/98 Small
F.I. = 1.8 @ 576 nm SPRING
UNKNOWN

A2-11



A3: RESULTS OF ANALYSIS FOR TRACER TEST 3 (TINOPAL CBS-X)

RECORD OF DYE-TRACER TEST RESULTS

Tracer Test No. 3 Location Dickson County, TN LANDFILL

Injection Date 1/13/98 Tracing Agent TINOPAL CBS-X OPTICAL BRIGHTENER (COTTON DETECTORS)

Date of Collection	12/9/97	12/16	1/7/98	1/14	1/16	1/21	1/26	1/30	2/6	2/11
Time Since Dye Injection										

ID	Location of Dye Detector	Back-ground	Results (Use qualitative codes below, or enter fluorometer readings)								
			12/9/97	12/16	1/7/98	1/14	1/16	1/21	1/26	1/30	2/6
1	BAPTISM FORK	B-	B-	B-	N	N	N	N	N	N	N
2	SULLIVAN WELL	NR	NR	B-	N	N	N	N	N	N	N
3	NEAR SULLIVAN SPRING	B-	B-	B-	N	N	N	N	N	N	N
4	DK-21 WELL	B-	B-	B-	N	N	NR	N	N	N	N
4A	AT LAKE BELOW DAM	NR	NR	B-	N	N	N	N	N	N	N
5	SULLIVAN SPRING	B-	B-	B-	N	N	N	N	N	N	N
6	F-86 WELL	-	-	-	-	-	-	-	-	-	-
7	ROADSIDE POND	B-	B-	B-	N	N	NR	N	N	N	N
8	F-91 WELL	NR	B-	B-	P ¹	N	NR	N	N	N	N
9	WET DEPRESSION	B-	B-	B-	N	N	NR	N	N	N	N
10	COUNTY LANDFILL	-	-	-	-	-	-	-	-	-	-
11	ARMSTRONG WELL	NR	B-	B-	N	N	NR	N	N	N	N
12	WETLAND AT SUMP	B-	B-	B-	WP ²	N	NR	N	N	WP ²	N
13	CITY LANDFILL	-	-	-	-	-	-	-	-	-	-
14	CATTAILS	B-	B-	B-	N	NR	NR	N	N	N	N

All Fluorometer Readings in: Unit Fluorescent Intensity Concentration (ppb)

- | | |
|-------------------------------------|---|
| N Negative (No Dye Detected) | B- No Background |
| WP Weakly Positive Dye Detection | B+ Significant (problematic) Background |
| P Positive Dye Detection | NR Dye Detector Not Recovered (high water last, etc.) |
| EP Extremely Positive Dye Detection | - Detector not Installed |

Remarks/ Interpretation
1. POSITIVE RECOVERY OF TINOPAL CBS-X CONFIRMED ON CHARCOAL DETECTOR AT #8 (SEE SPECTROFLUOROGRAPH, A3-
2. COTTON APPEARED WEAKLY FLUORESCENT UNDER UV-LIGHT, NOTHING RECOVERED ON CHARCOAL DETECTORS - NO TINOPAL CBS-X RECOVERED AT #12

RECORD OF DYE-TRACER TEST RESULTS

Tracer Test No. 3 Location DICKSON COUNTY, TN LANDFILL
 Injection Date 1/13/98 Tracing Agent TINOPAL CBS-X OPTICAL BRIGHTENER
(COTTON DETECTORS)

Date of Collection	12/9/97	12/16	1/7/98	1/14	1/14	1/21	1/26	1/30	2/6	2/11
Time Since Dye Injection										

ID	Location of Dye Detector	Back-ground	Results (Use qualitative codes below, or enter fluorometer readings)								
14A	HUMANE SOCIETY	B-	B-	B-	N	N	NR	N	N	N	N
15	DK-9 WELL	NR	B-	B-	N	N	NR	N	N	N	N
16	SEEP UNDER TREE	B-	B-	B-	N	N	NR	N	N	N	N
17	PAYNE SPRING	NR	B-	B-	N	N	N	N	N	N	N
18	WORLEY FURN. BR. (MOUTH)	B-	B-	B-	N	N	N	N	N	N	N
19	TICE SPRING	B-	B-	B-	N	N	NR	N	N	N	N
20	DONEGAN SP. #2	B-	B-	B-	N	N	N	N	N	N	N
21	DONEGAN SPRING	NR	B-	B-	N	N	N	N	N	N	N
22	BAKER BR.	B-	B-	B-	N	N	N	N	N	N	N
23	REDOEN SP.	B-	B-	B-	N	N	N	N	N	N	N
24	BRUCE SP.	NR	B-	B-	N	N	N	N	N	N	N
25	FIEDER SP.	NR	B-	B-	N	N	N	N	N	N	N
25A	SOMERALL SPRING	NR	B-	B-	N	N	N	N	N	N	N

All Fluorometer Readings in: Unit Fluorescent Intensity Concentration (ppb)

- N Negative (No Dye Detected)
- WP Weakly Positive Dye Detection
- P Positive Dye Detection
- EP Extremely Positive Dye Detection
- B- No Background
- B+ Significant (problematic) Background
- NR Dye Detector Not Recovered (high water, lost, etc.)
- Detector not installed

Remarks/ Interpretation

RECORD OF DYE-TRACER TEST RESULTS

Tracer Test No. 3 Location DICKSON COUNTY, TN LANDFILL

Injection Date 1/13/98 Tracing Agent TINOPAL CBS-X OPTICAL BRIGHTENER
 COTTON DETECTORS

Date of Collection	2/20/98	2/27	3/6	3/20	4/3	5/18	6/16	7/8	7/29	8/19
Time Since Dye Injection										

ID	Location of Dye Detector	Back-ground	Results							
			(Use qualitative codes below, or enter fluorometer readings)							
1	BAPTISM FORK	N	N	N	N					
2	SULLIVAN WELL	N	N	N	N					
3	NEAR SULLIVAN SPRING	N	N	N	N					
4	DK-21 WELL	N	N	N	N					
4A	AT LAKE BELOW DAM	N	NR	N	N					
5	SULLIVAN SPRING	N	N	N	N					
6	F-86 WELL	I	I	I	I					
7	ROADSIDE POND	N	N	N	N					
8	F-91 WELL	N	N	NR	N					
9	UGT DEPRESSION	N	N	N	N					
10	COUNTY LANDFILL	I	I	I	I					
11	ARMSTRONG WELL	N	N	N	N					
12	WETLAND AT SUMP	N	N	N	N					
13	CITY LANDFILL	I	I	I	I					
14	CATTAILS	N	N	N	N					

All Fluorometer Readings in: Unit Fluorescent Intensity Concentration (ppb)

- N Negative (No Dye Detected)
- WP Weakly Positive Dye Detection
- P Positive Dye Detection
- EP Extremely Positive Dye Detection
- B- No Background
- B+ Significant (problematic) Background
- NR Dye Detector Not Recovered (high water, lost, etc.)
- Detector not installed

Remarks/ Interpretation

RECORD OF DYE-TRACER TEST RESULTS

Tracer Test No. _____ Location DICKSON COUNTY, TN LANDFILL

Injection Date _____ Tracing Agent _____

Date of Collection	2/20/98	2/27	3/6	3/20	4/3	4/30	5/18	6/16	7/8	8/19
Time Since Dye Injection										

ID	Location of Dye Detector	Back-ground	Results (Use qualitative codes below, or enter fluorometer readings)								
			2/20/98	2/27	3/6	3/20	4/3	4/30	5/18	6/16	7/8
14A	HUMANE SOCIETY	N	N	N	N						
15	DK-9 WELL	N	N	N	N						
14	SEEP UNDER TREE	N	N	N	N						
17	PAYNE SPRING	N	N	N	N						
18	WORLEY FURN. BR. (MOUTH)	N	N	N	N						
19	TICE SPRING	NR	N	N	N						
20	DONEGAN SP. #2	N	N	N	N						
21	DONEGAN SPRING	N	N	N	N						
22	BAKER BR.	N	N	N	N						
23	REDDEN SP.	N	N	N	N						
24	BRUCE SP.	N	N	N	N						
25	FIELDER SP.	N	N	N	N						
25A	SOMERALL SPRING	N	N	N	N						

All Fluorometer Readings in: Unit Fluorescent Intensity Concentration (ppb)

- N Negative (No Dye Detected)
- WP Weakly Positive Dye Detection
- P Positive Dye Detection
- EP Extremely Positive Dye Detection
- B- No Background
- B+ Significant (problematic) Background
- NR Dye Detector Not Recovered (high water, lost, etc.)
- Detector not installed

Remarks/ Interpretation

RECORD OF DYE-TRACER TEST RESULTS

Tracer Test No. 3 Location DICKSON COUNTY, TN LANDFILL

Injection Date 1/13/98 Tracing Agent TINOPAL CBS-X OPTICAL BRIGHTENER
 SUPPLEMENTAL ANALYSIS OF CHARCOAL

Date of Collection	2/20/98	2/27	3/6	3/20	4/3	4/30	5/18	6/16	7/8	7/29
Time Since Dye Injection										

ID	Location of Dye Detector	Back-ground	Results								
			(Use qualitative codes below, or enter fluorometer readings)								
1	BAPTISM FORK										
2	SULLIVAN WELL	.08	.09	.08	.09	.16	φ	.09	.11	.12	.10
3	NEAR SULLIVAN SPRING	.30	.21	.88	.10	.18	.17	.23	.30	.31	.20
4	DK-21 WELL	.68	1.6	1.39	1.0	1.8	.80	.64	.26	.35	.77
4A	AT LAKE BELOW DAM	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5	SULLIVAN SPRING	.18	.34	.19	.20	.30	.14	.32	.25	.13	.44
6	F-86 WELL										
7	ROPOSIOE POND										
8	F-91 WELL										
9	JET DEPRESSION										
10	COUNTY LANDFILL										
11	ARMSTRONG WELL										
12	WETLAND AT SUMP										
13	CITY LANDFILL										
14	CATTAILS										

All Fluorometer Readings In: Unit Fluorescent Intensity Concentration (ppb)

- N Negative (No Dye Detected)
- WP Weakly Positive Dye Detection
- P Positive Dye Detection
- EP Extremely Positive Dye Detection
- B- No Background
- B+ Significant (problematic) Background
- NR Dye Detector Not Recovered (high water, lost, etc.)
- Detector not Installed

Remarks/ Interpretation

RECORD OF DYE-TRACER TEST RESULTS

Tracer Test No. 3 Location DICKSON COUNTY, TN LANDFILL

Injection Date 1/13/98 Tracing Agent TINYPAL CBS-X OPTICAL BRIGHTENER
SUPPLEMENTAL ANALYSIS OF CHARCOAL

Date of Collection	8/19/98	9/10	9/29						
Time Since Dye Injection									

ID	Location of Dye Detector	Back-ground	Results						
			(Use qualitative codes below, or enter fluorometer readings)						
1	BAPTISM FORK								
2	SULLIVAN WELL	.22	.24	.19					
3	NEAR SULLIVAN SPRING	.74	.74	.52					
4	DK-21 WELL	2.2	1.6	1.9					
4A	AT LAKE BELOW DAM	NA	NA	NA					
5	SULLIVAN SPRING	1.4	.29	.45					
6	F-86 WELL								
7	ROADSIDE POND								
8	F-91 WELL								
9	UGT DEPRESSION								
10	COUNTY LANDFILL								
11	ARMSTRONG WELL								
12	WETLAND AT SWAMP								
13	CITY LANDFILL								
14	CATTAILS								

All Fluorometer Readings in: Unit Fluorescent Intensity Concentration (ppb)

- N Negative (No Dye Detected)
- WP Weakly Positive Dye Detection
- P Positive Dye Detection
- EP Extremely Positive Dye Detection
- B- No Background
- B+ Significant (problematic) Background
- NR Dye Detector Not Recovered (high water, lost, etc.)
- Detector not installed

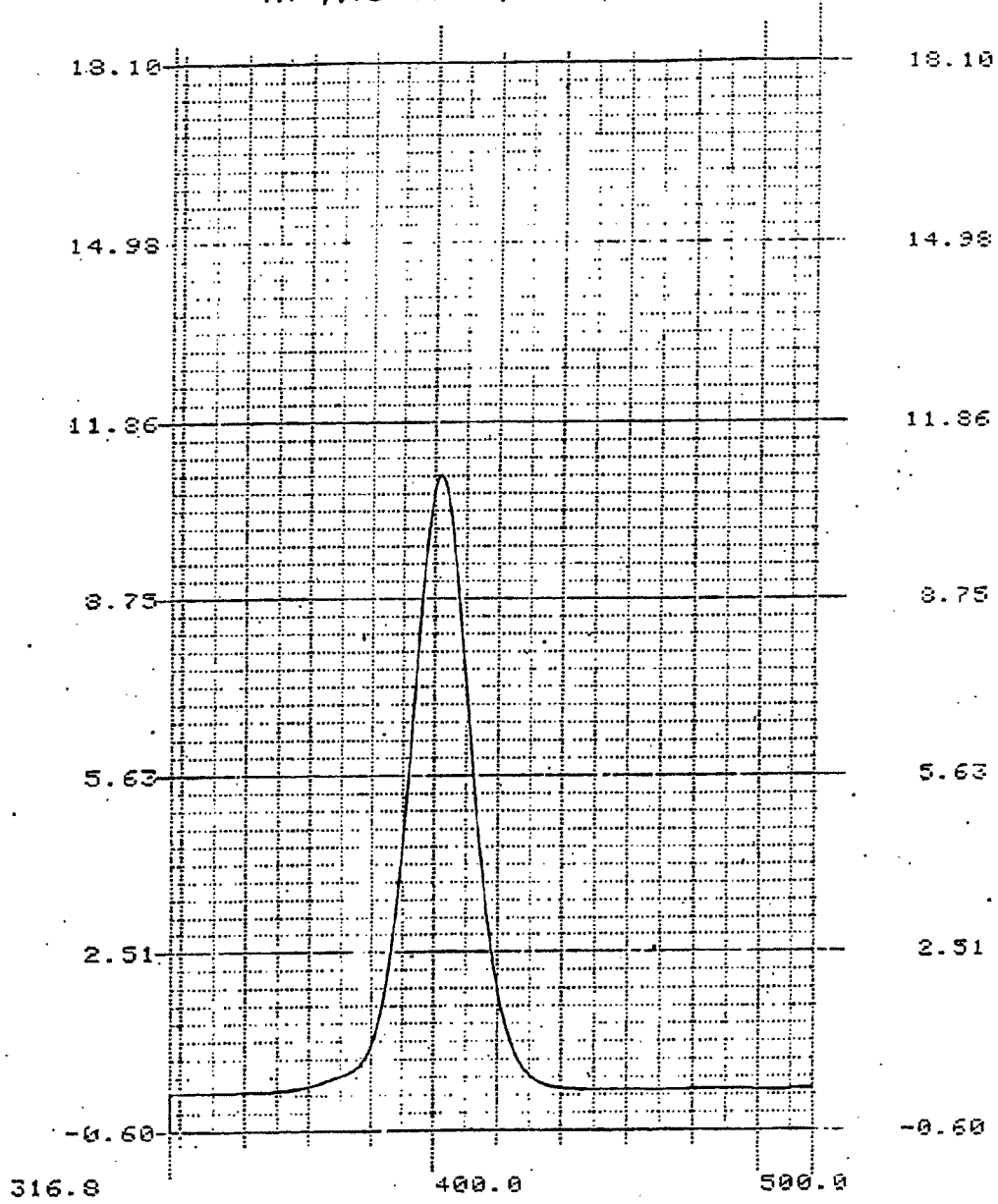
Remarks/ Interpretation

N8 1/14/98 (F-91 well)

AS-7

F.I = 11.0 @ 402 nm

TINOPAL CBS-X O.B.

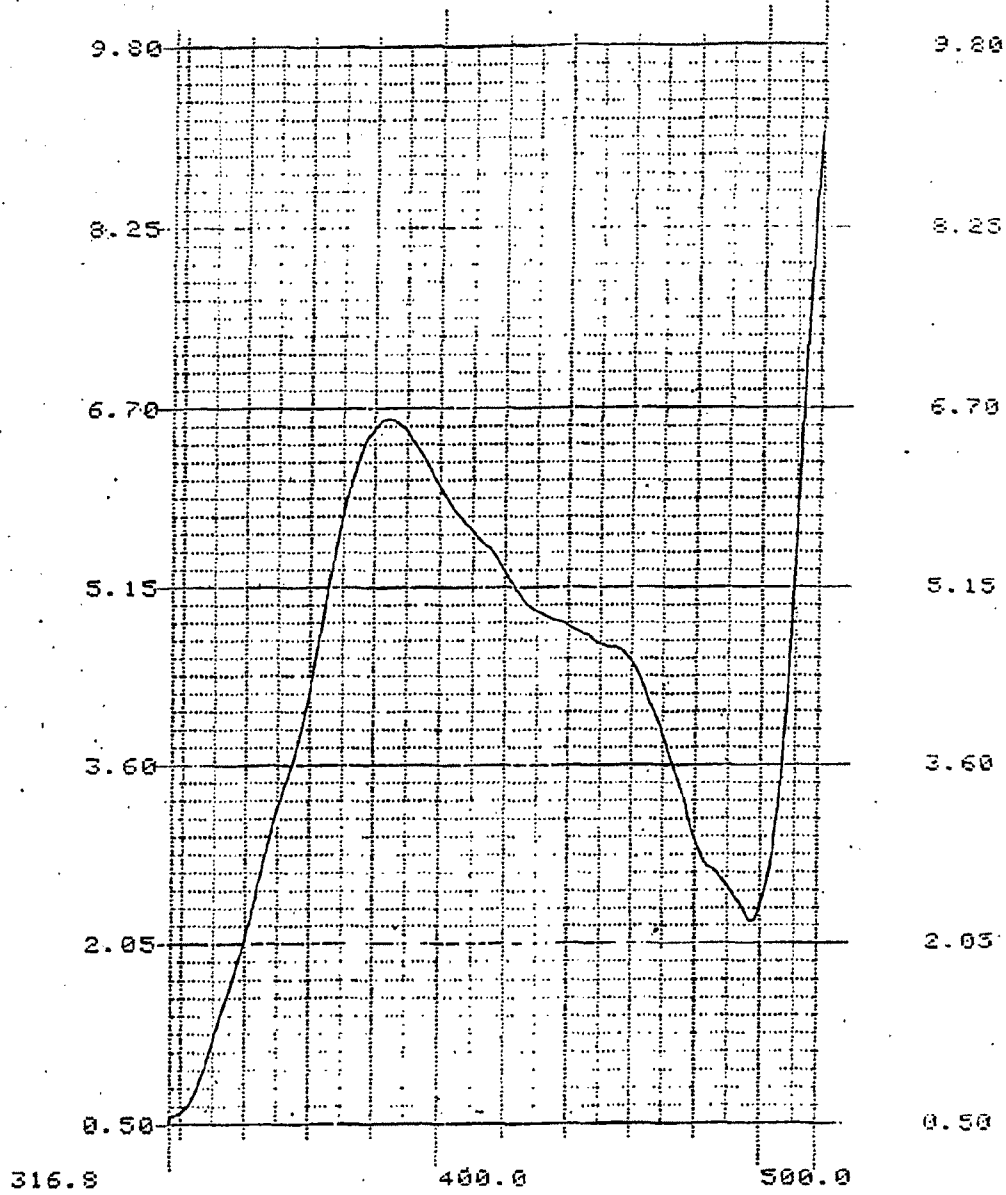


TN12 1/14/98 (WETLAND)

A3-8

F.I. = 6.6 @ 384 nm

UNKNOWN

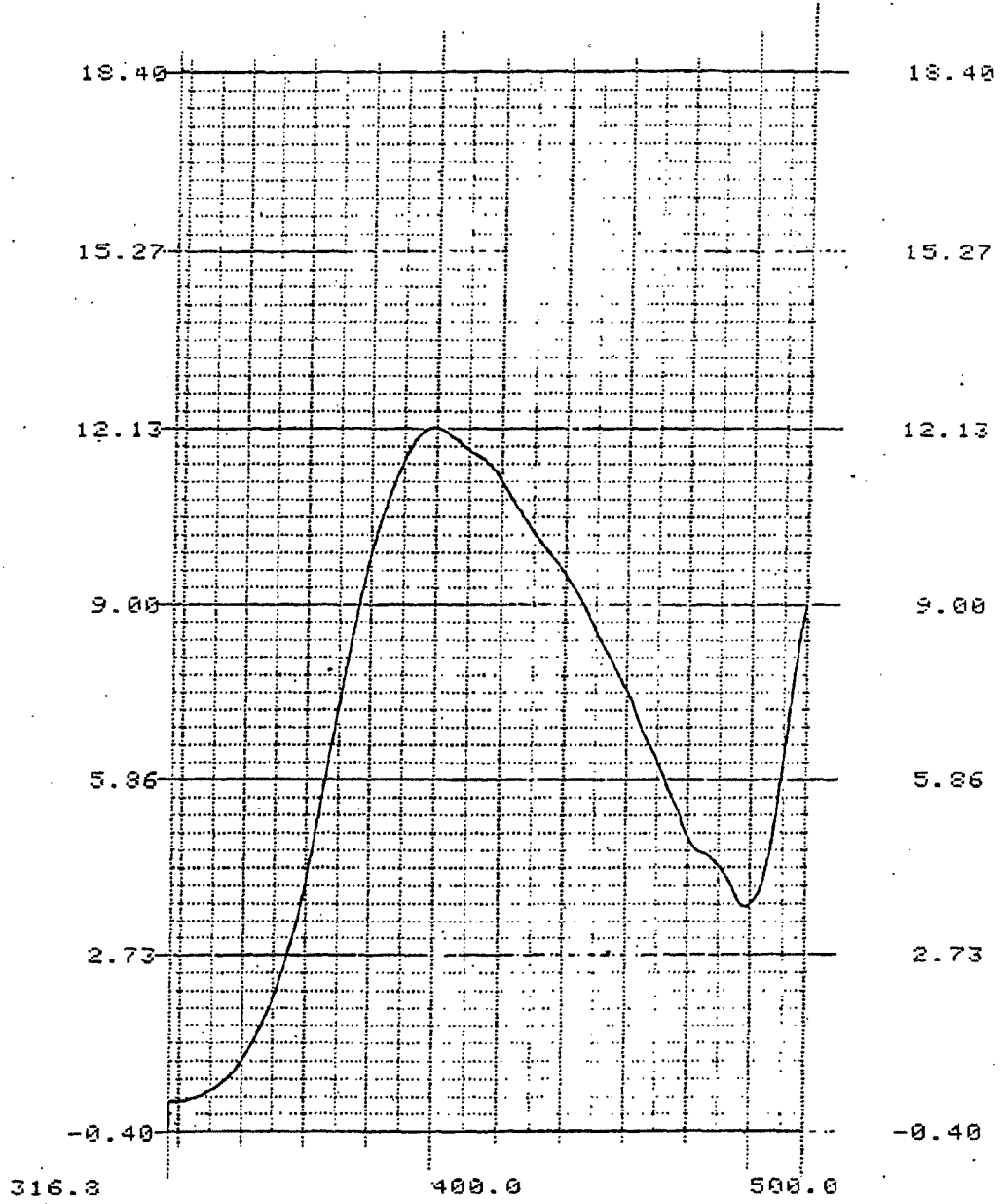


TN12 2/6/98

F.I. = 12.2 @ 399 nm

UNKNOWN SOURCE

A3-9



**A4: EXAMPLE SPECTROFLUOROGRAPHS SHOWING CHARACTERISTIC
WAVEFORMS AND EMISSION PEAKS FOR TRACER DYES USED IN THE
INVESTIGATION**

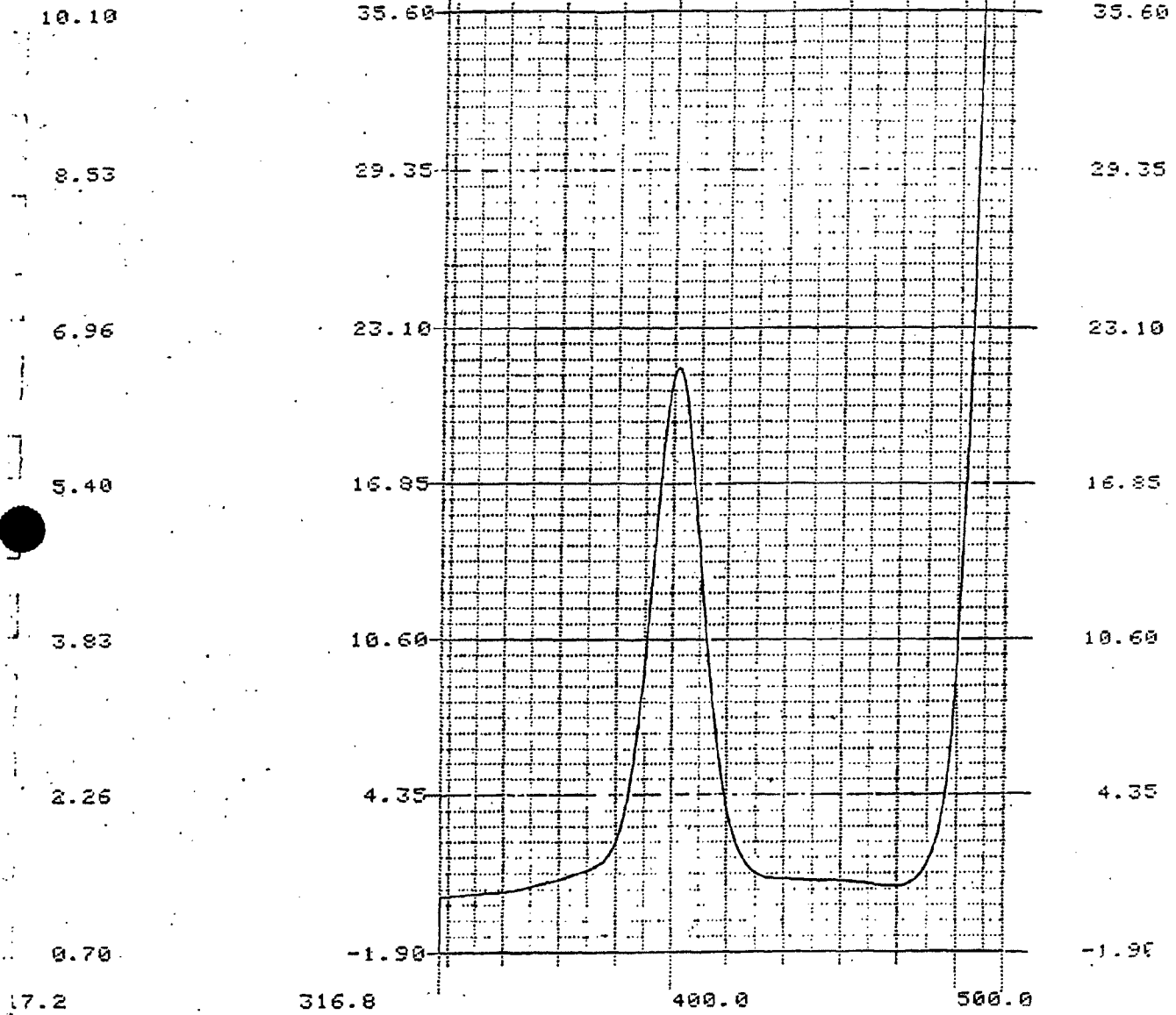
(KENTUCKY FIELD SITE)

EXAMPLE OF
TINOPAL CBS-X O.B.

PAGE A4-1

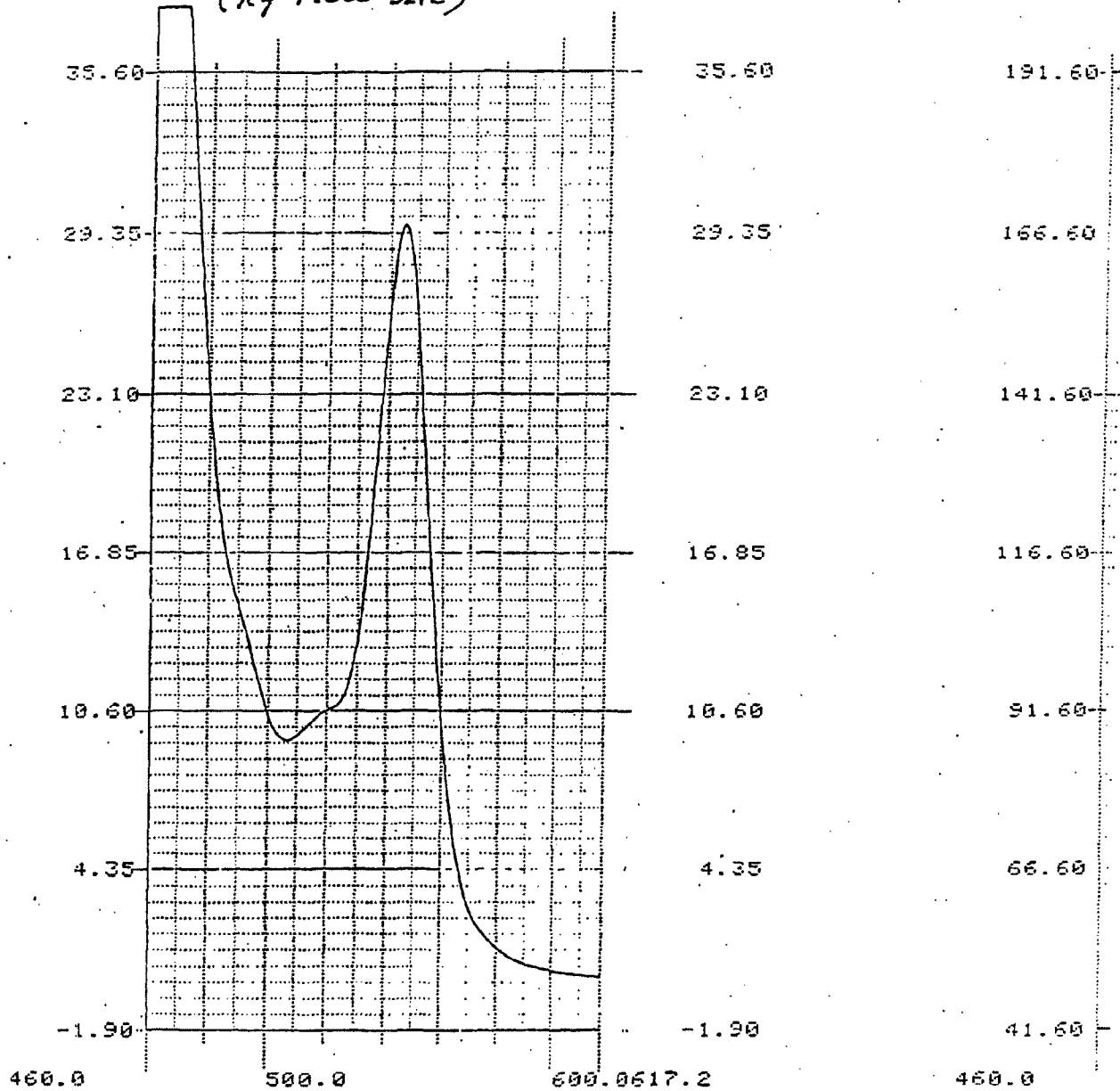
PEAK @ 402 nm

~~FIELD~~ (KY FIELD SITE)



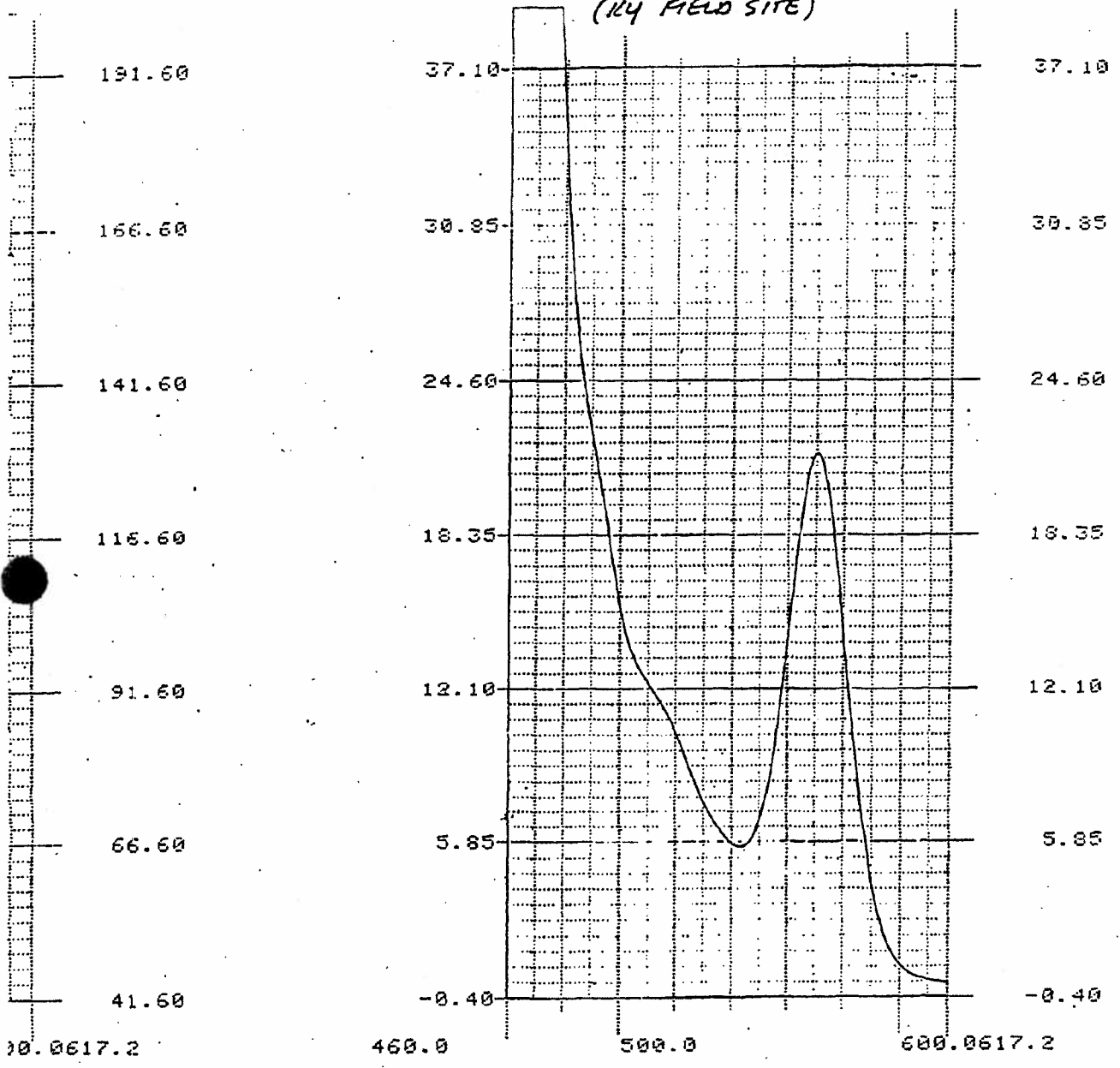
EXAMPLE OF
EOSINE D3
PEAK @ 545 nm
(KY FIELD SITE)

A4-2



A4-3

EXAMPLE OF
RHODAMINE WT
PEAK @ 570 nm
(104 FIELD SITE)



DWS/L&C

Division of Water Supply
401 Church Street
6th Floor, L&C Tower
Nashville, TN 37243-1549

November 10, 1993

Patricia Thompson
DRE Environmental Services, Inc.
111 Westwood Place, Suite 420
Brentwood, TN 37027

Dear Ms. Thompson:

In response to your submittal of an application for authorization for a Class V Underground Injection Well, this Division agrees with your approach for the injection of dye for the purpose of determining the direction of the ground water flow at the Scovill, Inc., 201 Tennsco Drive, Dickson, Tennessee location.

This authorization is for the injection of four simultaneous tracers using three different dyes. The insertion of one dye (Fluorescein) in two temporary wells and two different dyes (Rhodamine WT and Eosin) in two other temporary wells. The amount of dye and the exact dye to be used at the designated wells must be reported to the Division no later than 24 hours prior to injection.

Due to the location of the injection wells being in the proximity of a possible contamination area, it will be necessary to treat all cuttings and fluids which are extracted from the injection wells as hazardous waste until laboratory analysis indicates otherwise. In concurrence with the Division of Solid Waste Management (DSWM), the Division of Water Supply (DWS) requires a composite soil and a water sample taken from each injection well and analyzed for Volatile Organic Compounds (VOC). Should it be determined that the soils and/or water has VOC concentrations which exceed Drinking Water Standards the soil and/or water will be disposed of according to the RCRA Facility Investigation plan which has been submitted and approved by the DSWM. All laboratory results are to be sent to the Division of Water Supply and the Division of Solid Waste Management.

Before the injection wells can be plugged and abandoned Underground Injection Control (UIC) Regulation 1200-4-6-

.09(9)(a) the Department is to receive thirty (30) days advance notice of the intent to plug and abandon either an injection or monitoring well in order to permit Departmental personnel to witness the procedure. Within ninety (90) days after completion of plugging, the permittee shall provide to the Department documentation that the well was adequately plugged and abandoned 1200-4-6-.09(b). The wells must be abandoned according to the general plugging and abandonment standards as stipulated in UIC Regulation 1200-4-6.09(6).

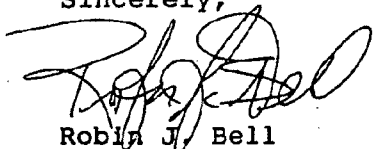
The Dye Tracing Evaluation Form must be filed with this office and the Division of Solid Waste Management no later than thirty (30) days after completion of the test.

This authorization to inject will expire two (2) years from the date of this letter. A completely new application will need to be filed with this Division prior to expiration in order to remain in compliance.

Our concurrence with your approach does not imply that this procedure is exempt from future changes or restriction in the UIC regulations.

Should you have any questions or comments please feel free to contact me at (615) 532-0169.

Sincerely,



Robin J. Bell
UIC Coordinator/Geologist
Ground Water Management Section