Idaho Department of Water Resources

Open File Report

FLUORESCENT DYE TRACER TESTS near the MALAD GORGE STATE PARK (Riddle well test)

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May 19, 2010

ABSTRACT

Through a cooperative effort between Idaho Power and the Idaho Department of Water Resources, two tracer tests were successfully completed near the Malad Gorge State Park during the fall of 2009 and spring of 2010. Dye was released in a domestic well located approximately 2865 feet south of the Gorge. Springs along the river edge in the Gorge and selected domestic wells were monitored for the presence of dye. Fluorescent dyes were used in a ‘two phased’ approach to determine the spatial distribution and the travel time of the dye. Results document that groundwater is flowing in a northwest direction from the injection well to the Gorge at an average linear flow velocity of 800 feet per day and a maximum flow velocity of 2,455 feet per day. Previous tracer tests in this area were completed by Farmer and Blew during 2009 using the Malad Gorge State Park picnic area well for dye release. The information gained and techniques developed from the previous tests were applied during these tracer tests.

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Purpose and Objectives

A groundwater tracer test using fluorescent dyes was implemented near the Malad Gorge State Park to track flow paths and define other baseline aquifer characteristics. Long-term goals for the tracer studies for the Eastern Snake Plain Aquifer (ESPA) are to provide additional information on aquifer flow characteristics of the ESPA starting in the discharge areas. This study is an additional step in developing information and technology to support an ongoing tracer program on the ESPA and this test supports previous tracer test data in this area. Tracer studies could provide flow data for the application of practices to manage and enhance the aquifer. Some of the goals for this test include an attempt to determine the following:

1. What is the hydraulic communication between a well and springs in the gorge?
2. What is the azimuth of the groundwater flow direction?
3. What is the groundwater flow velocity?
4. What is the spatial distribution or dispersion angle of the dye?
5. How fast will the dye flow out of the well?
6. How long does the pump need to be turned off during the test?
7. What will be the residual dye concentration in the well when the pump is turned back on?
8. Will water quality be affected?
9. What is the optimal sampling temporal and spatial frequency?
10. How much dye is needed to obtain a significant and discernable response?
11. What will be the resurgent concentration of dye in the springs?
12. What are any potential biological impacts from the dye?
13. Will the injection method using polyethylene tubing work?
14. Is the level of injection in the well correct at this location?
15. Will the test be a burden or an inconvenience for the well owner?
16. What is the cost of the test?

Geographic Setting

The Malad Gorge State Park is located approximately 90 miles southeast of Boise (Figure 1) and starts near where Interstate 84 crosses the upper part of the Gorge in Gooding County at T6S R13E, southern section 25 and northern section 36 (Figure 2). The Gorge in this area is about 225 feet deep with vertical walls of basalt and boulder talus slopes. Formation of the Gorge is attributed to cataract retreat of flood waters from the Bonneville Flood. No major landslides are discernable in this part of the Gorge. However, a bench about 20 feet higher than the river within a section of the talus slope extending from sample sites MG-1 to MG-5 may be the remnants of an old landslide. A domestic well located approximately 2865 feet south and east of the gorge was used as the site for the injection of dye. The elevation of the domestic well head is 3,276 feet determined from 100 post processed readings using a Trimble GeoXT 2005 set on the highest precision option and NAD83. On October 20th, 2009 the depth to water in the well was 180.12 feet or 3,096 feet elevation. The river and spring discharge elevations in the gorge range from 3,015 to 3,040 feet elevation using the same technique.

Figure 1. General location of the dye tracer test at the Malad Gorge State Park.

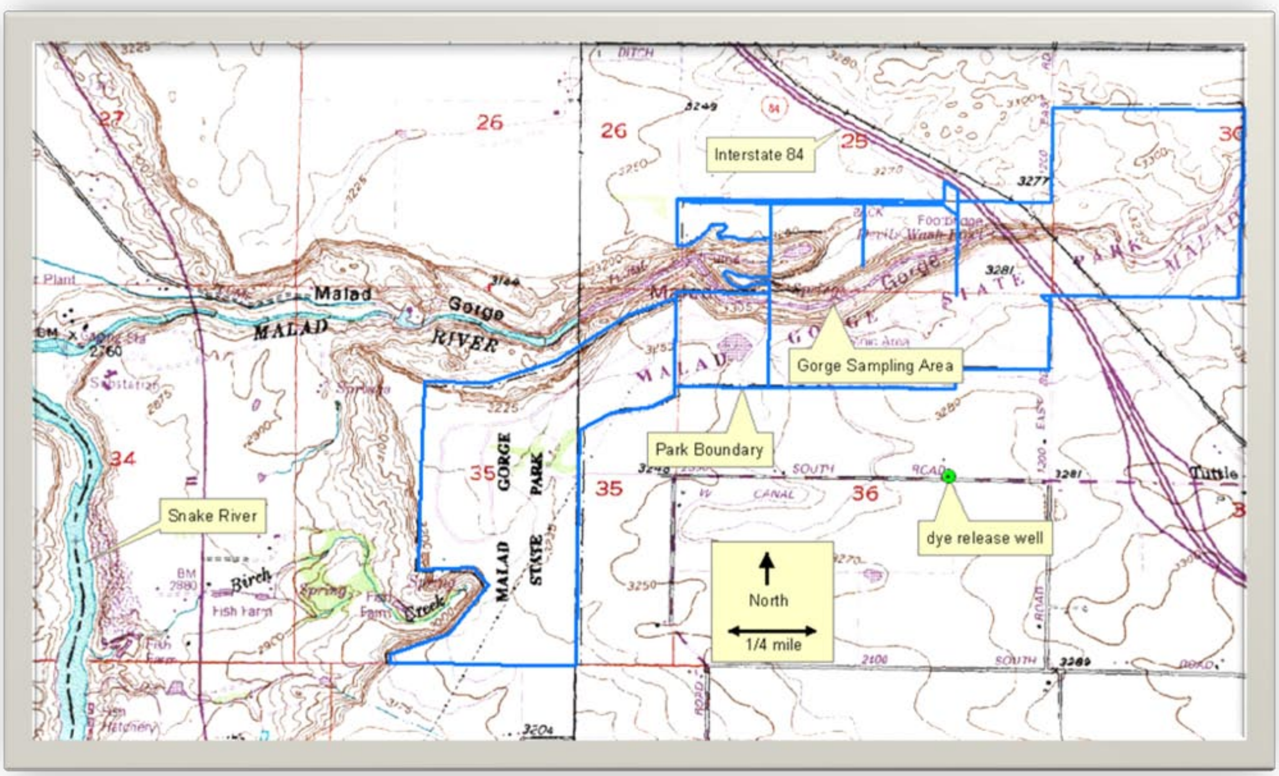

Figure 2. USGS topographic map of the site showing the dye release well south of the park boundary as the blue colored line.

Hydrogeologic Setting

The Snake River Plain is a major late Cenozoic tectonic/volcanic feature in the northern portion of the Basin and Range geologic region (Malde, 1991). The plain extends across southern Idaho for roughly 300 miles in a crescent shape. It is divided into two main sections identified as the western and eastern Snake River Plain. The western portion is about 40 miles wide, bounded by normal faults and has a northwest-southeast trend. Malde and Powers (1958) recorded at least 9,000 feet of displacement between the highlands to the north and the elevation of the plain today and concluded about 5,000 feet of displacement occurred in the early and middle Pliocene. The displacement started about 17 million years ago by rifting and down warping of the plain. The subsequent stretching of the crust produced a basin that began filling with sedimentary and volcanic rocks during the Miocene, Pliocene and Pleistocene (Malde, 1991).

The Bonneville Flood sculpted and augmented the Snake River Canyon from erosion and deposition approximately 15,000 years ago (Malde, 1991). It is theorized that several gorges were cut from the flood event through a process of cataract retreat. As with Niagra Falls, the plug pool erodes a less resistant lower level formation more easily than an overlying formation (Leet et al., 1978). Exposed at the mouth of the Malad Gorge is an in-situ outcrop of Glenns Ferry Formation (GFF) at an elevation of 2,934 feet. The cataract that formed the Gorge eroded the partially unconsolidated pillow rubble zone and probably the GFF which caused the overlying basalt to collapse. Springs in the canyon emerge from boulders and talus slopes near the edge of the Malad River. The actual outlets of springs are covered and each spring was selected based upon observed higher flow rates than adjacent springs, position, access and an even distribution of sampling sites.

A simple geologic model described in a previous dye tracer report by Farmer and Blew (2009) is used to provide the framework to assist hydrologic and tracer test interpretation. The well log for this test is shown in Appendix A with black cinders-loose noted from 210–230 feet depth. This description and elevation is consistent with a pillow basalt and associated brecciated material which is interpreted to be the same pillow zone and general geologic environment as described in Farmer and Blew (2009). Pillows and associated brecciated rubble are highly permeable and capable of transmitting and discharging large volumes of ground water at high velocities. The brecciated zone of the pillow layer, which maybe up to 45 feet thick and extend for up to 2 miles based on nearby well drilling logs, is more homogeneous and isotropic than the basalt flows. When considering the overall aquifer at a larger scale of many miles and the full thickness of the basalts overlying the GFF, the pillow brecciated zone creates greater heterogeneity in the flow system.

All vertical GPS elevation values have an average of +/- 3.5 feet error. The depth to water in the release well #26 was measured at 177.95 feet on March 1, 2010 which equates to an elevation of 3,098 feet (+/- 3.5 feet). The river pool elevation at sample site MG-3 is 3,028 feet (+/- 3.5 feet) for a difference between the well and river of approximately 70 feet. This level of accuracy was deemed sufficient given the unknown nature of the in-situ level of aquifer discharge covered under the talus slope. Applying the vertical error to 70 feet equals a range of 66.5 to 73.5 feet over a distance of 2,865 feet between well #26 and MG-3. The actual elevation of the water table at the point of emergence could be many feet above the river pool elevation but using the above values would equate to a groundwater hydraulic gradient ranging from 0.023 to 0.026.

GENERAL PROCEDURE AND METHODS

The following general approach proved efficient for time, supplies, and sampling/analysis costs. It also provided a high resolution breakthrough curve on a one hour frequency that is essentially impossible if done manually without a SCUFA instrument. The dye of choice for this study was Sodium Fluorescein and Rhodamine WT. Fluorescein, a green colored fluorescent dye, was first synthesized by Adolf von Baeyer in 1871 and it's the most commonly used dye for groundwater tracing studies and second most common for surface water tracing. Sodium Fluorescein (Acid Yellow 73 – CAS # 518-47-8) can be detected in a fluorometer at low concentrations of 0.01 parts per billion (ppb) or 10 parts per trillion. Fluorescein is also known as Drug and Cosmetic Yellow 8 which is an ingredient in some consumer products. A two phase approach similar to and consistent with previous tests performed at the Malad Gorge State Park picnic area well was used at this site due to accessibility issues matched with sampling frequency needs for the desired results (Farmer and Blew, 2009).

Phase one used Fluorescein dye to delineate the spatial distribution of the dye cloud as well as the location with the greatest amount of dye resurgence. Phase two used Rhodamine WT dye with additional charcoal samplers placed to increase the resolution of the spatial distribution from the first test. Domenico and Schwartz (1990) describe RWT as one of the 'ideal' tracers that do not react with other ions or the geologic medium to any appreciable extent thus making it a conservative tracer. Aulenbach et. al. (1978) demonstrated that RWT and tritium tracers produced similar break through curves in a delta sand aquifer which further supports the RWT as a conservative tracer.

A submersible fluorometer and datalogger (SCUFA) was deployed during Phase II at the sample site where the greatest amount of Fluorescein dye was detected during Phase I. The SCUFA recorded the concentration of dye with time to provide a concentration breakthrough curve which was then used to determine the travel time as well as the character of the dye cloud as it passed out of the spring. A ground water velocity was then calculated using the linear distance between the dye release well and the sample site/spring.

Phase I Description

Collection of background water samples for Phase I started on Sept 22, 2009 at numerous spring locations and wells and continued for 13 days after the injection of the dye. Pre-test sampling was done to insure Fluorescein from previous testing or other source of fluorescent material was not present prior to initiation of the test. Water sample collection consisted of 50 mL grab samples, and the analysis was done with a calibrated bench top fluorometer model TD700. Charcoal packets were placed in selected springs on October 15th prior to the injection of dye which occurred on October 20th. The packets were left in place until they were retrieved on November 4th for a total of 20 days and 15 days after dye was released.

Figure 3 shows the location of the sample sites as green circles noted as MG-1, 3, 5, 7, 9, 11, then MG-12 through 23, and 4 wells which include the Park picnic area well #24, well #25, the dye release well #26 and well #27. The charcoal packets were placed at locations with high spring or groundwater discharge flowing into the river. Ground water discharge was observed at other locations but at lower rates. Nine grams of coconut shell activated carbon (#10 mesh size) were placed inside each packet made from fiberglass screen which is similar to Ozark Underground Laboratory's method noted on page 1 (Aley, 2003). Charcoal packets serve as 'sentries' that are constantly immersed in water and will absorb dye as it passes through the packet during the test period. This means the information gained from the charcoal packets is integrative over the test period.

On October 20th, 2009 charcoal packets were deployed at nearby wells inside toilet tanks and 50 mL water samples collected from both the wells and springs in the Gorge. Then at 12:30 pm, three pounds of Fluorescein dye mixed with 6 gallons of potable water was released into well #26 through polyethylene tubing down to 205 feet below top of the casing (T.O.C.). The pump was turned off for two days and the water level in the well was 178.13 feet below T.O.C. On October 22nd, the pump was turned back on and two water samples collected. One was field inspected for presence of dye and later analyzed in the lab which was negative. The other water sample was immediately delivered to a local private lab to test for Coliform bacteria. No Coliform was detected in the water sample.

Calibration solutions were mixed according to the standard procedure detailed in the 1986 USGS document titled 'Fluorometric Procedures for Dye Tracing' by Wilson et al. A Turner Designs model TD700 lab fluorometer was configured for both Rhodamine WT and Fluorescein dyes with a detection limit of 0.01 ppb. The concentration of standards used for Phase I were 0.1, 1.0, 5, 50, 100 and deionized water as a blank. The instrument is operated and maintained in accordance with the manufacturers' manual. The calibration solutions, water samples and eluted charcoal samples were allowed to equilibrate to room temperature by at least 4 hours before use.

Both water samples and charcoal packet eluted solutions were analyzed with the TD700. The fluorometer was set on 'direct concentration mode' which uses an averaging process before the final value is displayed. Elution of dye from the charcoal samplers was done in accordance with the SOP outlined on page 7 from the document titled 'Procedures and Criteria Analysis of Fluorescein and Rhodamine WT Dyes in Water and Charcoal Samplers' (Aley, 2003). Fifty mL of the solution is poured over the charcoal in a glass container and capped for several days (Figure 4). The solution was then poured through a particulate filter into a 50 mL culture tube and inserted into the fluorometer. The same culture tube is used for each test and rinsed 3 times with deionized water. A control of charcoal soaked in deionized water was tested with a result of 0.05 ppb.

The pre-test and post-test sample results are shown in Figure 5. MG-3 and MG-5 received the largest amount of dye during the Fluorescein test. Slightly elevated levels were observed at MG-1.5 and MG-7 but it is unclear if these are responses to the dye or changes in background fluorescence. The natural background fluorescence or 'noise' for most of the sample sites ranged from 15 to 25 ppb with no discernable dye detection in any of the wells or other spring sites. Figure 6 shows the water sample results. Only sites MG-3 and 5 have a positive detection of dye which is consistent with the high concentrations from the charcoal sample results. The natural background fluorescence 'noise' in the water samples ranged from 0 to about 0.07 ppb.

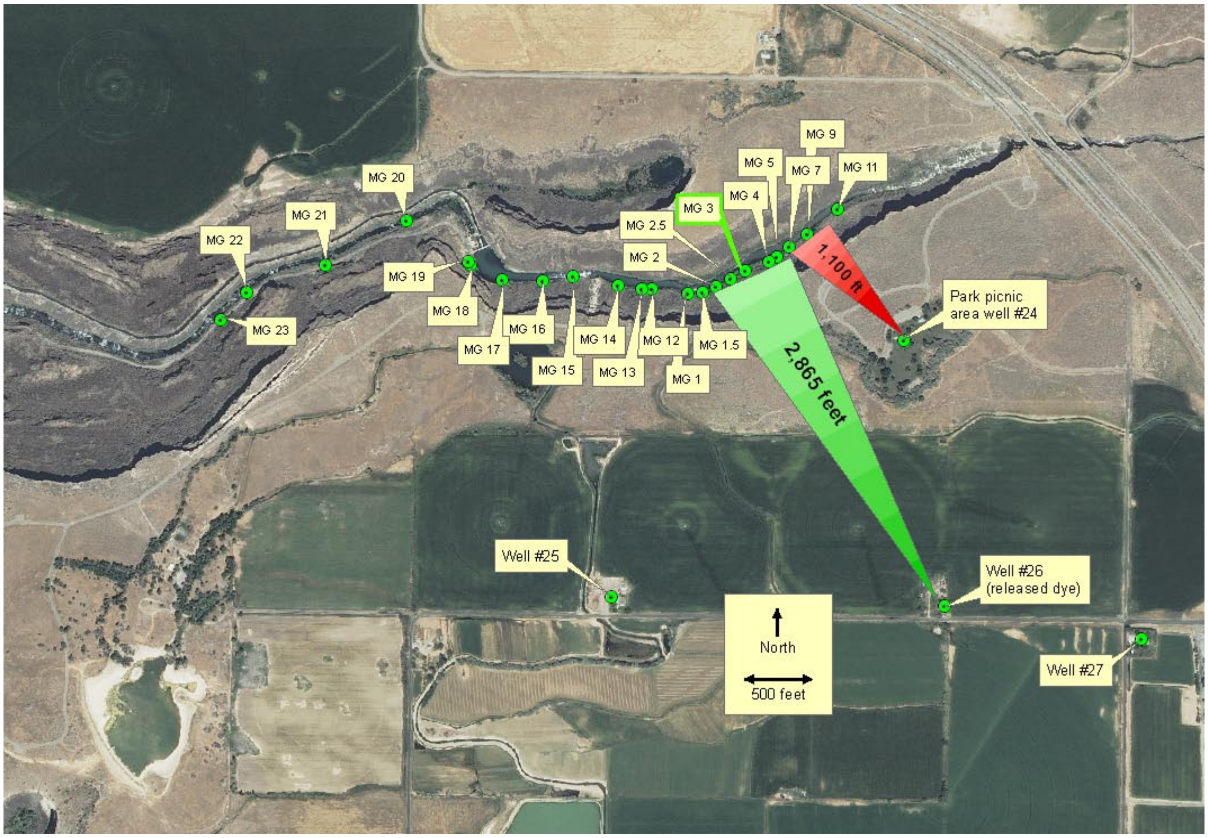

Figure 3. Tracer test sample sites with green circles and path of dye as the green triangle. Dye was detected at sites MG-3, 5, and 7 with MG-3 having the highest concentration from charcoal samplers. The previous dye trace location is noted as the red triangle.

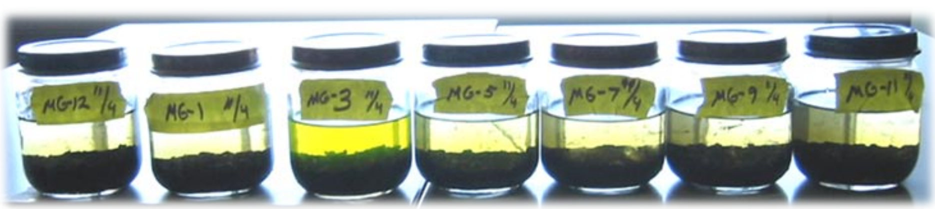

Figure 4. Charcoal soaking in eluting solution visually showing Fluorescein in MG-3 and lesser amount in MG-5.

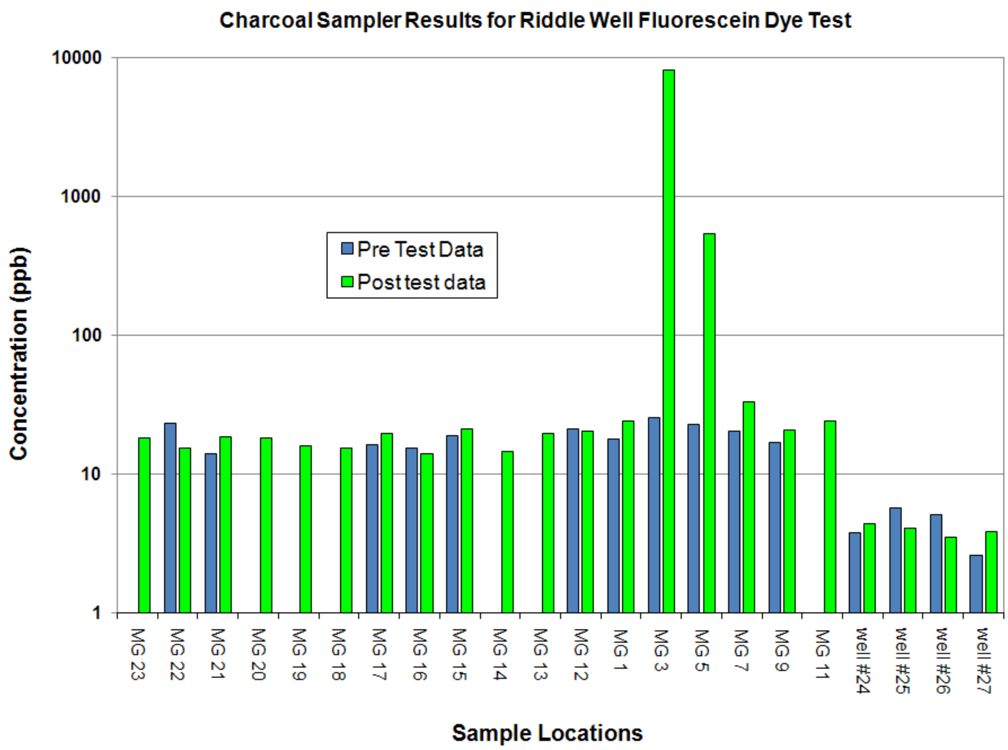

Figure 5. Data from charcoal packet analysis for Fluorescein on two scales. Dye was only detected at sites MG-3 and 5 with maybe a small amount at MG-7.

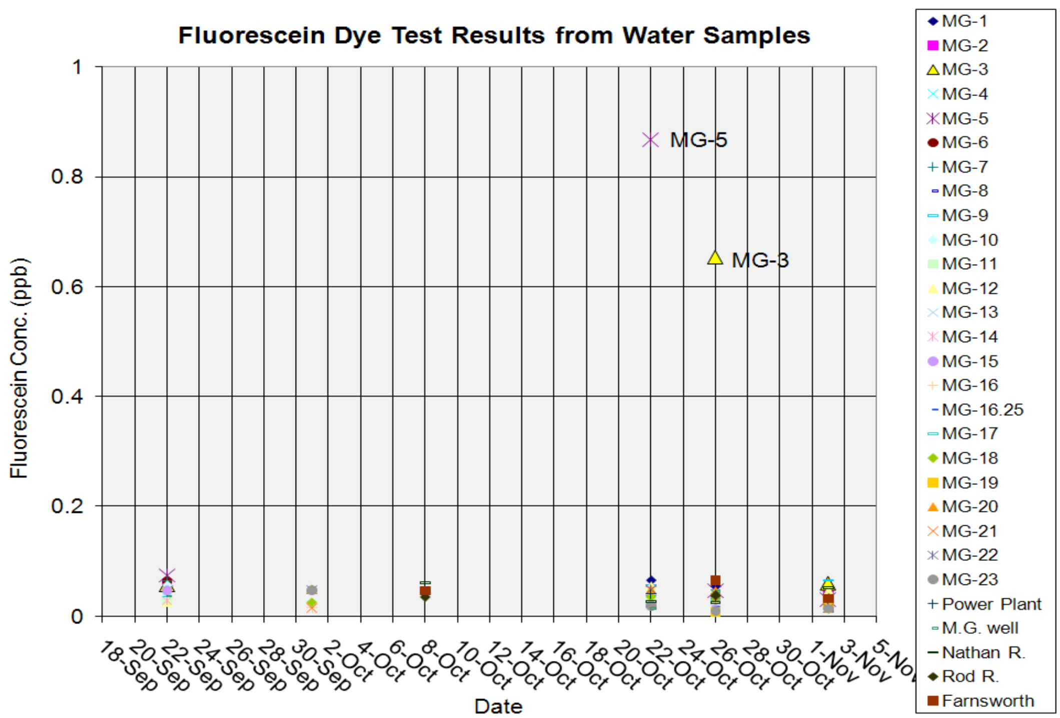

Figure 6. Results for water sample analysis before, during and after the test. Dye was only detected at sites MG-3 and 5.

Phase II Description

The preferred hydraulic flow path was determined from data collected during Phase I. Then in Phase II, 2 pounds of Rhodamine WT (RWT) active ingredient was mixed with 4 gallons of water and released on March 1st, 2010 at 2:00 pm. The Rhodamine WT dye was released using the same methods as in Phase I and injected at 203 feet below T.O.C. The depth to water in the well was measured at 177.95 feet below T.O.C. The well was not pumped for 24 hours after which water samples were collected from the well for analysis of dye and bacteria. After water samples were collected, the well was disinfected as part of an established safety protocol.

During Phase II, charcoal samplers were placed at sites MG-1, 1.5, 2, 2.5, 3, 4 and 5 (Figure 3). Sample sites MG-2 and 4 were not included in Phase I, so during Phase II charcoal packets were deployed at these sites and the additional sites MG-1.5 and 2.5. The additional sampling sites were added to increase the spatial resolution of dye detection in this area and refine the cone of dispersion. On March 12, 2010 the charcoal samplers were retrieved, chilled, and taken to the lab for analysis.

Processing the charcoal samplers for RWT used the same lab methods as described in the previous section (Phase I). The Fluorometer was ‘blanked’ with deionized water and standards of 1 and 100 ppb. Deionized water was poured through a particulate filter into a 50 mL culture vial and analyzed with a result of 0.0 ppb fluorescence. A fresh unused sample of charcoal from the same container used for the field samples was soaked in DI water and filtered and tested resulting in a fluorescence of -0.1 ppb. The negative value is due to fine particles of charcoal absorbing or blocking the light.

A Turner Designs “Self Contained Underwater Fluorescent Apparatus” or SCUFA was deployed at sample site MG-3 and calibrated using deionized water and 1.0 ppb RWT standard solution. Prior to deployment, the SCUFA was programmed to record direct water concentration of RWT every hour. The SCUFA has automatic temperature compensation and it also measures turbidity, which was zero throughout the test even though two storm systems with precipitation passed through this area. The unit was inserted into 3-inch diameter black plastic pipe with holes drilled at an angle to allow water to flow through but block sunlight. It was secured in a shady area of high spring flow at MG-3 about 3 feet in elevation above the pool level of the river.

Figure 9 shows single peak response breakthrough curve for the RWT with a maximum concentration of about 1.8 ppb. A few spikes occurred in the data but they are insignificant and the trend is clearly defined. Turbidity was not a factor in this test based on the zero levels. The curve exhibits a classic shape with a steeper rising limb and a more gradual recession limb. Also, the slope of the recession limb and character of the tail suggest that longitudinal dispersion and sorption were low and the slug was well constrained.

The time of passage for the dye cloud was approximately one week with the initial breakthrough occurring 28 hours after dye release. The center of mass, based on the mean concentration, occurred 3.6 days or 86 hours after release which provided a time of travel for the average linear velocity of 800 feet per day. This value is similar to the previous Park well test of 880 feet per day. The charcoal packet RWT concentration at MG-3 was 388 ppb with a peak water concentration recorded by the SCUFA measured 1.8 ppb. The distance between sites MG-2 and MG-5 is 500 feet and the distance between MG-1.5 and MG-7 is 700 feet. The distance between the well and site MG-3 is 2,865 feet which equates a mechanical dispersivity ratio of 4.0 to 5.7.

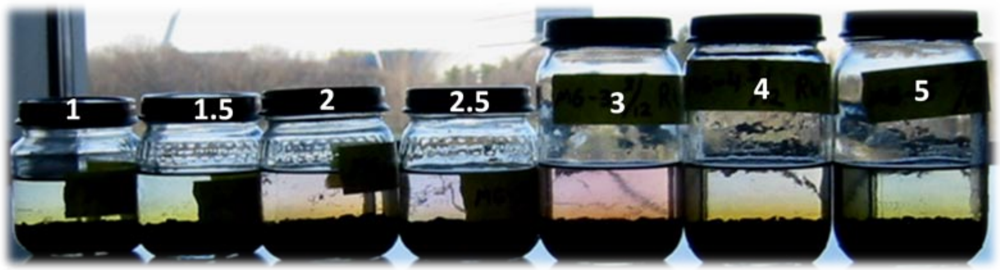

Figure 7. Charcoal soaking in eluting solution visually showing Rhodamine WT in MG-2, 2.5 and 3. Jar order from left to right correlate to the site numbers in Figure 6 below from MG-1 through MG-5.

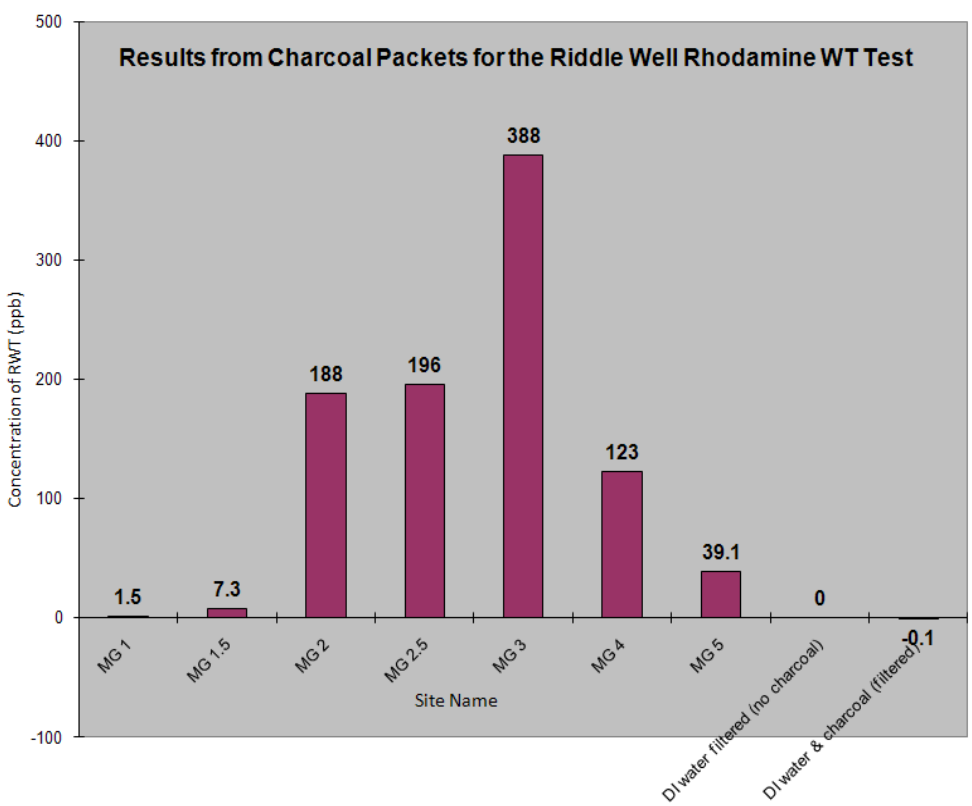

Figure 8. Concentrations of Rhodamine WT from charcoal packet samplers which is shown in the previous Figure 6.

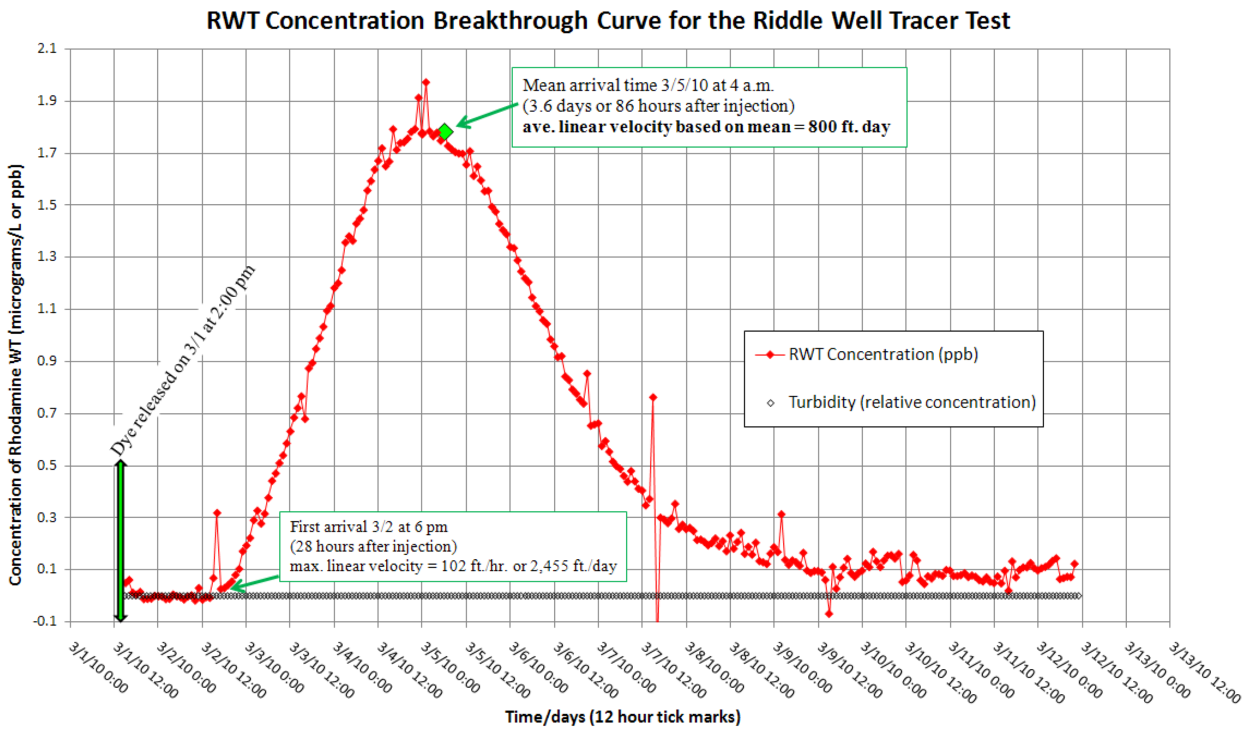

Figure 9. Concentration breakthrough curve for RWT showing a single peak response with a 'sharp' interface of the rising and recession limbs at site MG-3.

Aquifer hydraulic conductivity can be estimated using tracer data with the caveat that approximately 9% of the linear distance is talus slope. The effective porosity is estimated from professional judgment and assumed to be nearly the same as porosity obtained from published literature.

Using the equation $K = P_e * V_{ave} \div I$ where:

- "P_e" is effective porosity estimated from field observation and from published literature (Dominico and Schwartz, 1990) (Fetter, 1988) (Kruseman and Ridder, 1991) at 15% and then 30%.
- "V_{ave}" is average linear velocity based on the center of mass from the dye cloud at 800 feet per day.
- "I" is the hydraulic gradient from dh/dl = 0.0245.

Therefore:

- If P_e is 15% then K is approximately 4,900 feet per day.

  or,
- If P_e is 30% then K is approximately 9,800 feet per day.

If the actual elevation of the aquifer emergence is 20 feet higher in elevation or 3,048 feet, then the gradient (I) would be approximately 0.018. This estimate is based on the bench feature and talus above the river/springs but also on vegetation growth at the level of the bench, water flowing across the bench and the wall behind the bench. Using the same equation, porosity and average linear velocity the following values would be:

- If P_e is 15% and gradient is 0.018 then K is approximately 6,700 feet per day.
  or,
- If P_e is 30% and gradient is 0.018 then K is approximately 13,300 feet per day.

Results and Discussion

Results from the charcoal packet analysis from Phase I indicated that site MG-3 spring had the highest resurgent amount of dye with an eluted concentration of 8,160 ppb. This data suggests that MG-3 spring has the best hydraulic communication with the well used for dye injection. The combined charcoal results from both Phase I and II indicate the transverse dispersion of the dye was constrained between MG-2 through MG-5 with possibly small amounts in sites MG-1.5 and 7. The angle of dispersion measured from the well between MG-2 and 5 is approximately 10-12 degrees. The main flow path is based on the azimuth between the well and MG-3 which is 330 degrees. It is interpreted that the dye was transported through a brecciated pillow zone.

The results from Phase I allowed for targeting the placement of the SCUFA in Phase II. The results from Phase II were consistent with Phase I data and provided greater refinement of dispersion, travel time, dye break through characteristics, center of mass response, what amount of dye injected results in concentrations at the spring, how fast the dye moves out of the well, and provided quantitative data to calculate aquifer parameters. The first arrival of RWT dye at MG-3 spring was 28 hours post injection and the center of mass of the dye cloud was determined to be 86 hours. Using the recorded travel times of the dye cloud, the average linear water velocity was 800 feet per day. It appears that most of the dye had passed out of site MG-3 by one week.

This data will be used to develop additional studies utilizing wells that are farther from the Gorge. It also provides data on water movement within the ESPA and can potentially be used to help refine ground water models. The studies also provide legitimacy to the use of fluorescent tracers for studying ground water on the ESPA. The knowledge gained here is also being exported to other sites on the ESPA where additional tracer studies are currently being planned. A long-term strategy to utilize tracer studies is being implemented to help guide and direct efforts that can improve aquifer levels and increase spring discharge. Knowledge gained not only from the results of these studies but also the techniques developed can lead to a better understanding of water movement through the aquifer. Tracer studies could help target management practices to impact individual springs or spring complexes or avoid targeting individual springs. There is no doubt that dye tracer response may change in response to seasonal head changes in the aquifer and those head changes can also impact spring discharge. However, tracer studies may currently provide the best tool for placement of practices to target individual springs or spring complexes. Tracers may also help in refining water quality monitoring sites for aquifer recharge projects to ensure the protection of ground water resources. They may also aid in determining sources of contamination at some spring complexes.

ACKNOWLEDGEMENTS
This project is supported with financial assistance and personnel from Idaho Power and the Idaho Department of Water Resources. The data from this test will provided a solid foundation to gauge decisions for larger scale tests with invaluable support from the following. Thank you.

Idaho Department of Water Resource staff who assisted with the project include Hal Anderson, Brian Patton, Rick Raymondi, Sean Vincent, Dennis Owsley, Craig Tesch, Mike McVay, Allan Wylie and Taylor Dixon. Tom Aley with Ozark Underground Laboratories (OUL) provided volunteer support for project planning with guidance and recommendations for implementation. Staff with the Idaho Parks and Recreation and home/well owners were especially accommodating. The Idaho Department of Parks and Recreation were helpful and accommodating providing staff assistance and access to the Park well. Also, imperative to the project was the significant support from Larry Martin with the Water Resource Division of the U.S. National Park Service for the generous loan of over $10,000 worth of instruments, without which this project may not have occurred. The Idaho State Health Lab provided technical assistance from Beth Orde (Principal Chemist) to mix calibration standards and Jim McKean (Research Geomorphologist) with the U.S. Forest Service provided access to lab space to mix solutions and process samples.

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APPENDIX A – Well Drillers Report for Dye Release Well

App 891258

Form 238-7
6/02

IDAHO DEPARTMENT OF WATER RESOURCES

WELL DRILLER'S REPORT

Office Use Only	
Well ID No.	
Inspected by	
Twp ___ Rge ___ Sec ___	
___ 1/4 ___ 1/4 ___ 1/4	
Lat: : :	Long: : :

1. WELL TAG NO. D 0036881
DRILLING PERMIT NO. 836259
Water Right or Injection Well No.

2. OWNER:
Name Len Riddle
Address 2421 Richie Rd
City HAGERMAN State ID Zip 83332

3. LOCATION OF WELL by legal description:
You must provide address or Lot, Blk, Sub. or Directions to well.
Twp. 6 North ☐ or South ☒
Rge. 13 East ☒ or West ☐
Sec. 36, ___ 1/4 SW 1/4 NE 1/4
Gov't Lot ___ County Gooding
Lat: : : Long: : :
Address of Well Site 1176 E 2350 S City HAGERMAN
(Give at least name of road + Distance to Road or Landmark)
Lt. ___ Blk. ___ Sub. Name ___

4. USE:
☒ Domestic ☐ Municipal ☐ Monitor ☐ Irrigation
☐ Thermal ☐ Injection ☐ Other ___

5. TYPE OF WORK check all that apply (Replacement etc.)
☐ New Well ☐ Modify ☐ Abandonment ☒ Other

6. DRILL METHOD:
☒ Air Rotary ☐ Cable ☐ Mud Rotary ☐ Other ___

7. SEALING PROCEDURES

Seal Material	From	To	Weight / Volume	Seal Placement Method
Bentonite	0	18	4 sacks	poured

Was drive shoe used? ☒Y ☐N Shoe Depth(s) 198'
Was drive shoe seal tested? ☒Y ☐N How? AIR

8. CASING/LINER:

Diameter	From	To	Gauge	Material	Casing	Liner	Welded	Threaded
6"	+1	197	.250	steel	☒	☐	☒	☐
					☐	☐	☐	☐
					☐	☐	☐	☐

Length of Headpipe ___ Length of Tailpipe ___
Packer ☐Y ☐N Type ___

9. PERFORATIONS/SCREENS PACKER TYPE
Perforation Method ___
Screen Type & Method of Installation ___

From	To	Slot Size	Number	Diameter	Material	Casing	Liner
						☐	☐
						☐	☐
						☐	☐

10. FILTER PACK

Filter Material	From	To	Weight / Volume	Placement Method

11. STATIC WATER LEVEL OR ARTESIAN PRESSURE:
185 ft. below ground Artesian pressure ___ lb.
Depth flow encountered ___ ft. Describe access port or control devices: plate

12. WELL TESTS:
☐ Pump ☐ Bailer ☐ Air ☐ Flowing Artesian

Yield gal./min.	Drawdown	Pumping Level	Time

Water Temp. ___ Bottom hole temp. ___
Water Quality test or comments: ___
Depth first Water Encounter ___

13. LITHOLOGIC LOG: (Describe repairs or abandonment)

Bore Dia.	From	To	Remarks: Lithology, Water Quality & Temperature	Water Y	Water N
8	0	10	top soil		
	10	80	grey basalt		
	80	86	Red ash + cinders		
	86	129	Fractured grey basalt		
	129	135	brown basalt		
	135	158	Fractured grey basalt		
	158	167	cinders - lost circ		
	167	178	Fractured grey basalt		X
	178	197	black cinders - loose	X	
6	197	210	Fractured grey basalt	X	
	210	230	black cinders - loose	X	
			hole caved in @ 212'		

RECEIVED
OCT 21 2005
Department of Water Resources
Southern Region

Completed Depth ___ (Measurable)
Date: Started 9.22.05 Completed 9.23.05

14. DRILLER'S CERTIFICATION
I/We certify that all minimum well construction standards were complied with at the time the rig was removed.

Company Name AK Drilling Inc Firm No. 611
Principal Driller [signature] Date 9.26.05
and
Driller or Operator II Craig Egan Date 9.26.05
Operator I Lloyd Hayden Date 9.26.05
Principal Driller and Rig Operator Required.
Operator I must have signature of Driller/Operator II.

FORWARD WHITE COPY TO WATER RESOURCES

APPENDIX B – Miscellaneous Information

The NSS Bulletin - **ISSN 1090-6924**
Volume 46 Number 2: 21-33 - October 1984
A publication of the National Speleological Society

A Review of the Toxicity of Twelve Fluorescent Dyes Used for Water Tracing

P.L. Smart

Abstract

Toxicological information is reviewed for twelve fluorescent dyes used in water tracing, Fluorescent Brightener 28, Tinopal CBS-X, Amino G Acid, Diphenyl Brilliant Flavine 7GFF, Pyranine, Lissamine Yellow FF, Fluorescein, Eosine, Rhodamine WT, Rhodamine B, Sulphorhodamine B and Sulphorhodamine G. Mammalian tests indicate a low level of both acute and chronic toxicity. However, only three tracers could be demonstrated not to provide a carcinogenic or mutagenic hazard. These were Tinopal CBS-X, Fluorescein and Rhodamine WT. Rhodamine B is a known carcinogen and should not be used. In aquatic ecosystems, larval stages of shellfish and algae were the most sensitive. Persistent dye concentrations in tracer studies should not cause problems provided they are below 100 µg/l.

http://www.caves.org/pub/journal/PDF/V46/v46n2-Smart.htm

BRIGHT DYESMATERIAL SAFETY DATA SHEET
FLT YELLOW/GREEN LIQUID CONCENTRATE
PAGE 1 OF 3

MSDS PREPARATION INFORMATION

PREPARED BY:	T. P. MULDOON (937) 886-9100
DATE PREPARED:	1/01/05

PRODUCT INFORMATION

MAUNFACTURED BY:	KINGSCOTE CHEMICALS 3334 S. TECH BLVD. MIAMISBURG, OHIO 45342
CHEMICAL NAME	NOT APPLICABLE
CHEMICAL FORMULA	NOT APPLICABLE
CHEMICAL FAMILY	AQUEOUS DYE PRODUCT

HAZARDOUS INGREDIENTS

NONE PER 29 CFR 1910.1200

PHYSICAL DATA

PHYSICAL STATE	LIQUID
ODOR AND APPEARANCE	YELLOW/GREEN, WITH NO APPARENT ODOR
SPECIFIC GRAVITY	APPROXIMATELY 1.05
VAPOR DENSITY (mm Hg @ 25 ° C)	~23.75
VAPOR DENSITY (AIR =1)	~0.6
EVAPORATION RATE (Butyl Acetate = 1)	~1.8
BOILING POINT	100 degrees C (212 degrees F)
FREEZING POINT	0 degrees C (32 degrees F)
pH	8.0 OR ABOVE
SOLUBILITY IN WATER	HIGHLY SOLUBLE

FIRE HAZARD

CONDITION OF FLAMMABILITY	NON-FLAMABLE
MEANS OF EXTINCTION	WATER FOG, CARBON DIOXIDE, OR DRY CHEMICAL
FLASH POINT AND METHOD	NOT APPLICABLE
UPPER FLAMABLE LIMIT	NOT APPLICABLE
LOWER FLAMABLE LIMIT	NOT APPLICABLE
AUTO-IGNITION TEMPERATURE	NOT APPLICABLE
HAZARDOUS COMBUSTION PRODUCTS	NOT APPLICABLE
UNUSUAL FIRE HAZARD	NOT APPLICABLE

EXPLOSION HAZARD

SENSITIVITY TO STATIC DISCHARGE .... NOT APPLICABLE
SENSITIVITY TO MECHANICAL IMPACT .... NOT APPLICABLE

REACTIVITY DATA

PRODUCT STABILITY .... STABLE
PRODUCT INCOMPATIBILITY .... NONE KNOWN
CONDITIONS OF REACTIVITY .... NOT APPLICABLE
HAZARDOUS DECOMPOSITION PRODUCTS .... NONE KNOWN

TOXICOLOGICAL PROPERTIES

SYMPTOMS OF OVER EXPOSURE FOR EACH POTENTIAL ROUTE OF ENTRY:

INHALLATION, ACUTE .... NO HARMFUL EFFECTS EXPECTED.
INHALATION, CHRONIC .... NO HARMFUL EFFECTS EXPECTED.
SKIN CONTACT .... WILL TEMPORARILY GIVE SKIN A YELLOW/GREEN COLOR.
EYE CONTACT .... NO HARMFUL EFFECTS EXPECTED.
INGESTION .... URINE MAY BE A YELLOW/GREEN COLOR UNTIL THE DYE HAS BEEN WASHED THROUGH THE SYSTEM.
EFFECTS OF ACUTE EXPOSURE .... NO HARMFUL EFFECTS EXPECTED
EFFECTS OF CHRONIC EXPOSURE .... NO HARMFUL EFFECTS EXPECTED
THRESHOLD OF LIMIT VALUE .... NOT APPLICABLE
CARCINOGENICITY .... NOT LISTED AS A KINOWN OR SUSPECTED CARCINOGEN BY IARC, NTP OR OSHA.
TERATOGENICITY .... NONE KNOWN
TOXICOLOGY SYNERGISTIC PRODUCTS .... NONE KNOWN

PREVENTATIVE MEASURES

PERSONAL PROTECTIVE EQUIPMENT
GLOVES .... RUBBER
RESPIRATORY .... USE NISOH APPROVED DUST MASK IF DUSTY CONDITIONS EXIST.
CLOTHING .... PROTECTIVE CLOTHING SHOULD BE WORN WHERE CONTACT IS UNAVOIDABLE.
OTHER .... HAVE ACCESS TO EMERGENCY EYEWASH.

PREVENTATIVE MEASURES (CONT.)

ENGINEERING CONTROLS .... NOT NECESSARY UNDER NORMAL CONDITIONS, USE LOCAL VENTILATION IF DUSTY CONDITIONS EXIST.

SPILL OR LEAK RESPONSE .... CLEAN UP SPILLS IMMEDIATELY, PREVENT FROM ENTERING DRAIN. USE ABSORBANTS AND PLACE ALL SPILL MATERIALS IN WASTE DISPOSAL CONTAINER. FLUSH AFFECTED AREA WITH WATER.

WASTE DISPOSAL .... INCINERATE OR REMOVE TO A SUITABLE SOLID WASTE DISPOSAL SITE, DISPOSE OF ALL WASTES IN ACCORDANCE WITH FEDERAL, STATE AND LOCAL REGULATIONS.

HANDELING PROCEDURES AND EQUIPMENT .... NO SPECIAL REQUIREMENTS.

STORAGE REQUIREMENTS .... STORE AT ROOM TEMPERATURE BUT ABOVE THE FREEZING POINT OF WATER.

SHIPPING INFORMATION .... KEEP FROM FREEZING

FIRST AID MEASURES

FIRST AID EMERGENGY PROCEDURES

EYE CONTACT .... FLUSH EYES WITH WATER FOR AT LEAST 15 MINUTES. GET MEDICAL ATTENTION IF IRRITATION PERSISTS.

SKIN CONTACT .... WASH SKIN THOROUGHLY WITH SOAP AND WATER. GET MEDICAL ATTENTION IF IRRITATION DEVELOPS.

INHALATION .... IF DUST IS INHALED, MOVE TO FRESH AIR. IF BREATHING IS DIFFICULT GIVE OXYGEN AND GET IMMEDIATE MEDICAL ATTENTION.

INGESTION .... DRINK PLENTY OF WATER AND INDUCE VOMITING. GET MEDICAL ATTENTION IF LARGE QUANTITIES WERE INGESTED OR IF NAUSEA OCCURS. NEVER GIVE FLUIDS OR INDUCE VOMITING IF THE PERSON IS UNCONSCIOUS OR HAS CONVULSIONS.

SPECIAL NOTICE

ALL INFORMATION, RECOMMENDATIONS AND SUGGESTIONS APPEARING HEREIN CONCERNING THIS PRODUCT ARE BASED UPON DATA OBTAINED FROM MANUFACTURER AND/OR RECOGNIZED TECHNICAL SOURCES; HOWEVER, KINGSCOTE CHEMICALS MAKES NO WARRANTY, REPRESENTATION OR GUARANTEE AS TO THE ACCURACY, SUFFICIENCY OR COMPLETENESS OF THE MATERIAL SET FORTH HEREIN. IT IS THE USER'S RESPONSIBILITY TO DETERMINE THE SAFETY, TOXICITY AND SUITABILITY OF HIS OWN USE, HANDLING, AND DISPOSAL OF THE PRODUCT. ADDITIONAL PRODUCT LITERATURE MAY BE AVAILABLE UPON REQUEST. SINCE ACTUAL USE BY OTHERS IS BEYOND OUR CONTROL, NO WARRANTY, EXPRESS OR IMPLIED, IS MADE BY KINGSCOTE CHEMICALS AS TO THE EFFECTS OF SUCH USE, THE RESULTS TO BE OBTAINED OR THE SAFETY AND TOXICITY OF THE PRODUCT, NOR DOES KINGSCOTE CHEMICALS ASSUME ANY LIABILITY ARISING OUT OF USE BY OTHERS OF THE PRODUCT REFERRED TO HEREIN. THE DATA IN THE MSDS RELATES ONLY TO SPECIFIC MATERIAL DESIGNATED HEREIN AND DOES NOT RELATE TO USE IN COMBINATION WITH ANY OTHER MATERIAL OR IN ANY PROCESS.

END OF MATERIAL SAFETY DATA SHEET

BRIGHT DYES™ MATERIAL SAFETY DATA SHEET
FWT RED™ 200 LIQUID
PAGE 1 OF 3

MSDS PREPARATION INFORMATION

PREPARED BY:	T. P. MULDOON (937) 886-9100
DATE PREPARED:	1/1/08

PRODUCT INFORMATION

MAUNFACTURED BY:	KINGSCOTE CHEMICALS 3334 S. TECH BLVD. MIAMISBURG, OHIO 45342
CHEMICAL NAME	NOT APPLICABLE
CHEMICAL FORMULA	NOT APPLICABLE
CHEMICAL FAMILY	XANTHENE DYE FORM

HAZARDOUS INGREDIENTS

DESCRIPTION	%	T.L.V.	C.A.S. #
TRIMELLITIC ACID	3.0	NONE	528-44-9

	LD/50, SPECIES	LC/50, SPECIES
ORAL (MOUSE)	2500 MG/KG	NONE AVAILABLE
DERMAL (RABBIT)	NOT AVAILABLE	NOT AVAILABLE

PHYSICAL DATA

PHYSICAL STATE	LIQUID
ODOR AND APPEARANCE	DARK RED LIQUID WITH MILD ODOR
SPECIFIC GRAVITY	~1.15
VAPOR DENSITY (mm Hg @ 25 ° C)	NOT APPLICABLE
VAPOR DENSITY (AIR =1)	NOT APPLICABLE
EVAPORATION RATE (Butyl Acetate = 1)	NOT APPLICABLE
BOILING POINT	~ 100 degrees. C (212 degrees. F)
FREEZING POINT	~ 10 degrees C (14 degrees F)
pH	10.4 TO 10.8
SOLUBILITY IN WATER	VERY SOLUBLE

FIRE HAZARD

CONDITION OF FLAMMABILITY	NON-FLAMABLE
MEANS OF EXTINCTION	WATER FOG, CARBON DIOXIDE, DRY CHEMICAL, WEAR SCBA
FLASH POINT AND METHOD	NOT APPLICABLE
UPPER FLAMABLE LIMIT	NOT APPLICABLE
LOWER FLAMABLE LIMIT	NOT APPLICABLE
AUTO-IGNITION TEMPERATURE	NOT APPLICABLE
HAZARDOUS COMBUSTION PRODUCTS	BURNING MAY PRODUCE OXIDES OF CARBON & NITROGEN
UNUSUAL FIRE HAZARD	NOT APPLICABLE

EXPLOSION HAZARD

SENSITIVITY TO STATIC DISCHARGE	NOT APPLICABLE
SENSITIVITY TO MECHANICAL IMPACT	NOT APPLICABLE

REACTIVITY DATA

PRODUCT STABILITY	STABLE
PRODUCT INCOMPATIBILITY	DO NOT MIX WITH ACIDS
CONDITIONS OF REACTIVITY	NOT APPLICABLE
HAZARDOUS DECOMPOSITION PRODUCTS	SEE HAZARDOUS COMBUSTION PRODUCTS

TOXICOLOGICAL PROPERTIES

SYMPTOMS OF OVER EXPOSURE FOR EACH POTENTIAL ROUTE OF ENTRY:

INHALLATION, ACUTE	TRIMELLITIC ACID MAY CAUSE IRRITATION
INHALATION, CHRONIC	NOT KNOWN
SKIN CONTACT	MAY BE IRRITATING TO THE SKIN. WILL CAUSE TEMPORARY STAINING OF THE SKIN ON CONTACT.
EYE CONTACT	MAY CAUSE IRRITATION
INGESTION	URINE MAY BE A RED COLOR UNTIL THE DYE HAS BEEN WASHED THROUGH THE SYSTEM.
EFFECTS OF ACUTE EXPOSURE	DIRECT CONTACT MAY CAUSE IRRITATION TO THE EYES, SKIN, AND RESPIRATORY TRACT.
EFFECTS OF CHRONIC EXPOSURE	NOT KNOWN
THRESHOLD OF LIMIT VALUE	NOT APPLICABLE
CARCINOGENICITY	NOT LISTED AS A KINOWN OR SUSPECTED CARCINOGEN BY IARC, NTP OR OSHA.
TERATOGENICITY	NONE KNOWN
MUTAGENICITY	CONFLICTING EVIDENCE AS TO MUTAGENICITY OF THE DYE CONTAINED IN THIS PRODUCT.
TOXICOLOGY SYNERGISTIC PRODUCTS	NONE KNOWN

REGULATORY INFORMATION

SARA SECTION 303:	NONE FOUND
SARA (311, 312) HAZARD CLASS:	IMMEDIATE HEALTH HAZARD
SARA (313) REPORTABLE CHEMICAL (%):	NONE
METAL CONTENT:	THIS PRODUCT IS NOT A METALLIZED DYE
TSCS INVENTORY STATUS	ALL COMPONENTS ARE INCLUDED ON TSCA SECTION 8
CALIFORNIA PROPOSITION 65 CHEMICALS:	NONE
TSCA SECTION 12 (B) EXPORT REGULATIONS:	NOT SUBJECT TO TSCA 12 (b) EXPORT REGULATION

ECOLOGICAL INFORMATION

ECOTOXICOLOGICAL INFORMATION:	LC50: >320 mg/L RAINBOW TROUT (96 Hour) LC50: 170 mg/L DAPHINA MAGNA

NO DEVELOPMENTAL ABNORMALITIES OR TOXICITY TO OYSTER LARVAE AT 100 mg/L

PREVENTATIVE MEASURES

PERSONAL PROTECTIVE EQUIPMENT

GLOVES	RUBBER
RESPIRATORY	NONE REQUIRED UNDER NORMAL CONDITIONS
EYE PROTECTION	GOGGLES
CLOTHING	PROTECTIVE CLOTHING SHOULD BE WORN WHERE CONTACT IS UNAVOIDABLE.
OTHER	HAVE ACCESS TO EMERGENCY EYEWASH.
ENGINEERING CONTROLS	NOT NECESSARY UNDER NORMAL CONDITIONS USE LOCAL VENTILATION IF DUSTY CONDITIONS EXIST.
SPILL OR LEAK RESPONSE	CONTAIN AND CLEAN UP SPILL IMMEDIATELY, PREVENT FROM ENTERING FLOOR DRAINS. SWEEP POWDERS AND PLACE IN WASTE DISPOSAL CONTAINER, FLUSH AFFECTED AREA WITH WATER.
WASTE DISPOSAL	INCINERATE OR REMOVE TO A SUITABLE SOLID WASTE DISPOSAL SITE, DISPOSE OF ALL WASTES IN ACCORDANCE WITH FEDERAL, STATE AND LOCAL REGULATIONS.
HANDELING PROCEDURES AND EQUIPMENT	NO SPECIAL REQUIREMENTS.
STORAGE REQUIREMENTS	STORE AT ROOM TEMPERATURE BUT ABOVE THE FREEZING POINT OF WATER
SHIPPING INFORMATION	KEEP FROM FREEZING

FIRST AID MEASURES

FIRST AID EMERGENGY PROCEDURES

EYE CONTACT	FLUSH EYES WITH WATER FOR AT LEAST 15 MINUTES. GET MEDICAL ATTENTION IF IRRITATION PERSISTS.
SKIN CONTACT	WASH SKIN THOROUGHLY WITH SOAP AND WATER. GET MEDICAL ATTENTION IF IRRITATION DEVELOPS.
INHALATION	IF DUST IS INHALED, MOVE TO FRESH AIR. IF BREATHING IS DIFFICULT GIVE OXYGEN AND GET IMMEDIATE MEDICAL ATTENTION.
INGESTION	DRINK PLENTY OF WATER AND INDUCE VOMITING. GET MEDICAL ATTENTION IF LARGE QUANTITIES WERE INGESTED OR IF NAUSEA OCCURS. NEVER GIVE FLUIDS OR INDUCE VOMITING IF THE PERSON IS UNCONSCIOUS OR HAS CONVULSIONS.

SPECIAL NOTICE

ALL INFORMATION, RECOMMENDATIONS AND SUGGESTIONS APPEARING HEREIN CONCERNING THIS PRODUCT ARE BASED UPON DATA OBTAINED FROM MANUFACTURER AND/OR RECOGNIZED TECHNICAL SOURCES; HOWEVER, KINGSCOTE CHEMICALS MAKES NO WARRANTY, REPRESENTATION OR GUARANTEE AS TO THE ACCURACY, SUFFICIENCY OR COMPLETENESS OF THE MATERIAL SET FORTH HEREIN. IT IS THE USER'S RESPONSIBILITY TO DETERMINE THE SAFETY, TOXICITY AND SUITABILITY OF HIS OWN USE, HANDLING, AND DISPOSAL OF THE PRODUCT. ADDITIONAL PRODUCT LITERATURE MAY BE AVAILABLE UPON REQUEST. SINCE ACTUAL USE BY OTHERS IS BEYOND OUR CONTROL, NO WARRANTY, EXPRESS OR IMPLIED, IS MADE BY KINGSCOTE CHEMICALS AS TO THE EFFECTS OF SUCH USE, THE RESULTS TO BE OBTAINED OR THE SAFETY AND TOXICITY OF THE PRODUCT, NOR DOES KINGSCOTE CHEMICALS ASSUME ANY LIABILITY ARISING OUT OF USE BY OTHERS OF THE PRODUCT REFERRED TO HEREIN. THE DATA IN THE MSDS RELATES ONLY TO SPECIFIC MATERIAL DESIGNATED HEREIN AND DOES NOT RELATE TO USE IN COMBINATION WITH ANY OTHER MATERIAL OR IN ANY PROCESS.

END OF MATERIAL SAFETY DATA SHEET

BRIGHT DYES
Division of Kingscote Chemicals

WATER TRACING DYE
FLT YELLOW/GREEN PRODUCTS

TECHNICAL DATA BULLETIN

Bright Dyes Yellow/Green products are specially formulated versions of Xanthene dye, certified by NSF International to ANSI/NSF Standard 60 for use in drinking water. This dye is the traditional fluorescent water tracing and leak detection material and has been used for labeling studies from the beginning of the century. It may be detected visually, by UV light and by appropriate fluoremetric equipment. Today it is most often used visually. This dye has been used by the military to mark downed pilots for search and rescue operations over large water bodies. Visually the dye appears yellow/green, depending on its concentration and under UV light as lime green.

Based on biochemical oxygen demand (BOD) studies, the dye is biodegradable with 65% of the available oxygen consumed in 7 days. The dye is resistant to absorption on most suspended matter in fresh and salt water. However, compared to Bright Dyes FWT Red products it is significantly less resistant to degradation by sunlight and when used in fluoremetry, stands out much less clearly against background fluorescence. As always the suitability of these products for any specific application should be evaluated by a qualified hydrologist or other industry professional.

General Properties	Tablets	Liquids	Powders
Detectability of active ingredient [1]	Visual <100 ppb	Visual <100 ppb	Visual <100 ppb
Maximum absorbance wavelength [2]	490/520 nm	490/520 nm	490/520 nm
Appearance	Orange convex 1.6cm diameter	Reddish, brown aqueous solution	Orange fine powder
NSF (Max use level in potable water)	6.0 ppb	10.0 ppb	1.0 ppb
Weight	1.35 gms ± 0.05		
Dissolution Time [3]	50% < 3 minutes 95% < 6 minutes		50% < 3 minutes 95% < 6 minutes
Specific Gravity		1.05 ± 0.05 @ 25° C	
Viscosity [4]		1.8 cps	
pH		8.5 ± 0.5 @ 25° C	

Coverage of Products	One Tablet	One Pint Liquid	One Pound Powder
Light Visual	605 gallons	125,000 gallons	1,200,000 gallons
Strong Visual	60 gallons	12,500 gallons	120,000 gallons

Caution: These products may cause irritation and/or staining if allowed to come in contact wit the skin. The use of gloves and goggles is recommended when handling this product, as with any other dye or chemical.

[1] In deionized water in 100 ml flask. Actual detectability and coverage in the field will vary with specific water conditions.
[2] No significant change in fluorescence between 6 and 11 pH.
[3] (One tablet, 1 gram of powder), in flowing deionized water in a 10 gallon tank.
[4] Measured on a Brookfield viscometer, Model LV, UL adapter, 60 rpm @ 25° C.

Kingscote Chemicals, 3334 S. Tech Blvd., Miamisburg, Ohio 45342
Telephone: (937) 886-9100 Fax: (937) 886-9300 Web: www.brightdyes.com

WATER TRACING DYE
FWT RED PRODUCTS

BRIGHT DYES

Division of Kingscote Chemicals

TECHNICAL DATA BULLETIN

Bright Dyes FWT Red products are specially formulated versions of Rhodamine WT dye for convenient use in water tracing and leak detection studies. This bright, fluorescent red dye is certified by NSF International to ANSI/NSF Standard 60 for use in drinking water. It may be detected visually, by ultraviolet light and by appropriate fluorometric equipment. Today it is most often used visually. Visually the dye appears bright pink to red, depending on its concentration and under ultraviolet light as bright orange.

The dye is resistant to absorption on most suspended mater in fresh and salt water. Compared to Bright Dyes FLT Yellow/Green products it is significantly more resistant to degradation by sunlight and when used in fluorometry, stands out much more clearly against background fluorescence. As always the use and suitability of these products for any specific application should be evaluated by a qualified hydrologist or other industry professional.

General Properties	Tablets	FWT Red 25 Liquid	Powders
Detectability of active ingredient [1]	Visual <100 ppb	Visual <100 ppb	Visual <100 ppb
Maximum absorbance wavelength [2]	550/588 nm	550/588 nm	550/588 nm
Appearance	Dark red convex 1.6cm diameter	Clear dark red aqueous solution	Dark red fine powder
NSF (Max use level in potable water)	0.3 ppb	0.8 ppb	0.1 ppb
Weight	1.05 gms ± 0.05		
Dissolution Time [3]	50% < 3 minutes 95% < 6 minutes		50% < 3 minutes 95% < 6 minutes
Specific Gravity		1.03 ± 0.05 @ 25° C	
Viscosity [4]		1.3 cps	
pH		8.7 ± 0.5 @ 25° C	

Coverage of Products	One Tablet	One Pint Liquid	One Pound Powder
Light Visual	604 gallons	31,250 gallons	604,000 gallons
Strong Visual	60 gallons	3,125 gallons	60,400 gallons

Caution: These products may cause irritation and/or staining if allowed to come in contact wit the skin. The use of gloves and goggles is recommended when handling this product, as with any other dye or chemical.

To our best knowledge the information and recommendations contained herein are accurate and reliable. However, this information and our recommendations are furnished without warranty, representation, inducement, or license of any kind, including, but not limited to the implied warranties and fitness for a particular use or purpose. Customers are encouraged to conduct their own tests and to read the material safety data sheet carefully before using.

[1] In deionized water in 100 ml flask. Actual detectability and coverage in the field will vary with specific water conditions.

[2] No significant change in fluorescence between 6 and 11 pH.

[3] (One tablet, 1 gram of powder), in flowing deionized water in a 10 gallon tank.

[4] Measured on a Brookfield viscometer, Model LV, UL adapter, 60 rpm @ 25° C.

Rhodamine WT Reader

Readings on the Reactivity and Transport Characteristics of This Tracer

REGULATORY STANDARDS

- The standards established by the Environmental Protection Agency in the Federal Register (Vol. 63, No. 40) state the maximum Rhodamine WT concentrations to be 10 micrograms per liter for water entering a drinking water plant (prior to treatment and distribution) and 0.1 micrograms per liter in drinking water.

The US Geological Survey provides the regulatory standard references for information purposes ONLY. This information was obtained in August of 2004.

BACKGROUND FOR ANY APPLICATION

Characterization of fluorescence background in dye tracing. CC Smart, KC Karunaratne, *Environmental Geology*, **42**: 492, 2002. DOI: 10.1007/s00254-001-0510-y

Transient storage assessments of dye-tracer injections in rivers of the Willamette Basin, Oregon. A Laenen, KE Bencala, *Journal of the American Water Resources Association*, **37**(2): 367-377, 2001.

Fluorometric procedures for dye tracing. JF Wilson, ED Cobb, FA Kilpatrick, *USGS TWRI*, Bk3 ChapA12*,* Revised 1986.

A review of the toxicity of twelve fluorescent dyes used for water tracing. PL Smart, *The National Speleological Society Bulletin*, **46**: 21, 1984.

An evaluation of some fluorescent dyes for water tracing. PL Smart, IMS Laidlaw, *Water Resources Research*, **13**(1): 15, 1976.

REACTIVITY & TRANSPORT IN FIELD CONDITIONS

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COMMERCIAL PRODUCT INFORMATION

The US Geological Survey does *NOT* endorse or recommend commercial products.
The following is provided *ONLY* for identification and information purposes.

Rhodamine WT

Sensient Corporation
    http://www.sensient-tech.com/solutions/industrial_colors.htm
    800- 558-9892

Keystone Corporation
    http://www.dyes.com/
    800-522-4dye

Fluorometers

Seapoint Sensors, Inc
    http://www.seapoint.com/srf.htm
    603-642-4921

Turner Designs
    http://turnerdesigns.com
    877-316-8049

Opti-Sciences
    http://www.optisci.com/ps.htm

603-883-4400
YSI Inc.

Model 6130 Rhodamine WT Sensor
http://216.68.81.171/852568CB0010F86A/web+by+document+type/CF82E634926142FB85256AF8005E9FCF?Open
800-897-4151

International Chemical Safety Cards

http://www.itcilo.it/english/actrav/telearn/osh/ic/37299898.htm
http://www.inchem.org/documents/icsc/icsc/eics0325.htm

Compilation by Ken Bencala and Marisa Cox, September 23, 2005
http://water.usgs.gov/nrp/proj.bib/bencala.html
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Bulletin No. 103
Fluorescein

INTRODUCTION

Fluorescein was the first fluorescent dye used for water tracing work[1] and is still used for qualitative (visual) studies of underground contamination of wells. In recent years, Rhodamine WT has almost completely replaced fluorescein for flow measurements[2] and circulation, dispersion, and plume studies[3]. Nonetheless, fluorescein has a role in such studies, and can be used for masking, hydraulic model studies, and underground water studies.

ADVANTAGES

Fluorescein has the following advantages over other tracer dyes:

- Its low sorption rate is far better than Rhodamine B, and comparable to Rhodamine WT.
- It has a temperature coefficient of only −0.36% per degree C, about one-eighth of the temperature coefficient of rhodamine dyes[2,4].
- It emits a brilliant green fluorescence, which gives an excellent visual or photographic contrast against the backgrounds normally encountered in water transport studies. Therefore it is easy to visualize the progress of an experiment.
- It is more aesthetic than the red dyes. This is psychologically important, especially in ocean areas subject to the blooms of certain dinoflagellates, called "red tides." Less public resistance will be encountered using a dye that does not resemble red tide[5].

DISADVANTAGES

Fluorescein has been replaced by other dyes, principally Rhodamine WT, for the following reasons:

- It is rapidly destroyed by sunlight. Reference 4 reports that a 50% loss occurred in three hours of sunlight exposure, with dye being held in an Erlenmeyer flask. Other tests in an flat, uncovered Pyrex dish showed an almost complete destruction in two hours[6].
- Many naturally occurring fluorescent materials have similar characteristics and thus interfere with measurement. When carefully chosen optical filters are used, the situation is better than that reported in Reference 4, but higher concentrations are required to overcome the effect of higher and more variable "blank" fluorescence.
- Fluorescein is more pH-sensitive than rhodamine dyes. Fluorescence drops very sharply at pH values below 5.5. For optimum results, pH should be between 6 and 10.

MASKING TECHNIQUES

In river, harbor, and ocean tests, fluorescein can be used to mask the objectionable color of the rhodamine dyes. Tests show that Fluorescein is an effective mask, subject to the following conditions[6]:

- The concentration of fluorescein should be at least five times that of the active ingredients in the Rhodamine B or Rhodamine WT concentrate.
- Where the receiving water is shallow, clear, and in full sunlight, the dyes must be dispersed quite rapidly. With slow dispersion, the photosensitive fluorescein will be destroyed before the masking effect is complete.
- Masking is subjective. Lower (hence less costly) amounts of fluorescein may be effective, depending on water clarity, bottom color, wave action, etc. Small scale addition of the mixed dyes to the receiving water should be made in advance

of a large scale test. This test should be made on a bright sunny day, if possible.

- Note that fluorescein is not the ingredient measured. The optical filter and light source in the fluorometer read only rhodamine dye[7].

HYDRAULIC MODEL STUDIES

Fluorescein may be used in hydraulic model studies in exactly the same way that Rhodamine WT is used (See Refs. 2 and 3 for details).

The major advantage of using fluorescein is its visibility; the green color can be seen as the test proceeds. The major disadvantage is fluorescein's light sensitivity. It can be destroyed by light entering the test area, both from windows and from indoor lights, especially fluorescent ones.

Containers used for dye destruction tests must be transparent to light at shorter wavelengths. Clear borosilicate glass baking pans are handy, since they transmit light at shorter wavelengths than window glass or the glass envelopes of fluorescent lamps.

Test samples must be at low concentrations (around 0.2 PPM) so that the fluorescein in the bottom of the pan is not protected from the incident light by absorption of the fluorescein in the top of the pan.

In certain cases, deliberate destruction of the fluorescein by sunlight may be a convenience instead of a problem. Hydraulic models often recycle water. With the very stable Rhodamine WT, the concentration of dye in the entire system will build up over a sequence of several tests, requiring replacement of the water. If a shallow holding tank can be placed outdoors, the degradation of fluorescein by sunlight may eliminate the need to replace the water.

UNDERGROUND WATER STUDIES

Fluorescein can be used quantitatively for underground tests, subject to limitations imposed by the higher background of naturally occurring fluorescent materials.

An advantage of fluorescein in underground studies is its light sensitivity. Should it reach an open receiving body of water, the color will be less of a problem because it will disappear rapidly in the sunlight.

FILTER AND LIGHT SOURCE SELECTION

Using fluorescein, the following light sources and filters are recommended (referenced part numbers are specific to Turner Designs products):

	10-AU-005
Optical Kit	10-086 (Lamp and all filters are included in this kit.)
Light Source	10-089 Blue Lamp
Reference	10-063
Excitation	10-105
Emission	10-109R-C

We have found that background fluorescence can be very high in natural systems with the fluorescein setup. In most cases, this background should be adequately suppressed using the 10-AU fluorometer. If, however, background cannot be suppressed, a mask (attenuator) may be added to the excitation filter holder to reduce its diameter and the amount of light scatter. Attenuation by a factor of 5 can be obtained with the 10-318R Attenuator Plate.

Fluorescein, known as "Acid Yellow 73", "Acid Yellow T", "DNC Yellow 7", etc., can be obtained from the following sources (addresses checked and confirmed June 1996):

Pylam Products
Company, Inc.
1001 Stewart Avenue
Garden City, NY 11530
516/222-1750

Tricon Colors, Inc.
16 Leliarts Lane
Elmwood Park, NJ 07407
201/794-3800

LISSAMINE FF

The properties of uses of Lissamine FF are reported in Reference 9. Its spectral characteristics are similar to those of fluorescein, but it does not decompose as rapidly in sunlight. Use the fluorescein filters detailed above with Lissamine FF. Pylam Products (address shown above) offers

Lissamine FF as "Brilliant Acid Yellow 8G" or "Brilliant Sulphoflavine FFA".

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APPENDIX C – GPS Coordinates of Sample Sites in IDTM NAD83
(collected using a Trimble GeoXT 2005 set at maximum precision)

Site	X (meters)	Y (meters)
mg 1	2429484	1296373
mg 1.5	2429519	1296376
mg 2	2429548	1296389
mg 2.5	2429582	1296406
mg 3	2429614	1296423
mg 4	2429668	1296444
mg 5	2429687	1296455
mg 7	2429714	1296477
mg 9	2429755	1296504
mg 11	2429822	1296560
mg 12	2429405	1296383
mg 13	2429380	1296384
mg 14	2429328	1296391
mg 15	2429227	1296411
mg 16	2429158	1296401
mg 17	2429067	1296403
mg 18	2428995	1296436
mg 19	2428989	1296445
mg 20	2428850	1296535
mg 21 culvert	2428667	1296436
mg 22 below parking area	2428489	1296375
mg 23	2428431	1296316
Park picnic area well #24	2429972	1296268
Well #25	2429314	1295699
Well #26	2430064	1295676
Well #27	2430509	1295605