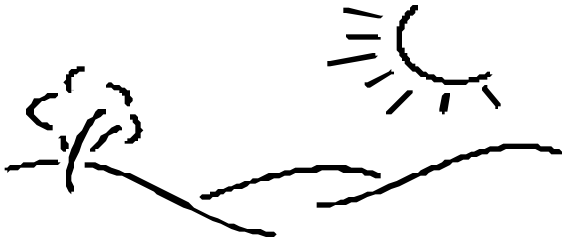
DYE TRACING

Objectives:
Students will:

- define how water can be traced as it moves underground,
- define parts-per-million and parts-per-billion,
- identify two dyes that are commonly used in hydrologic dye traces.



Materials:

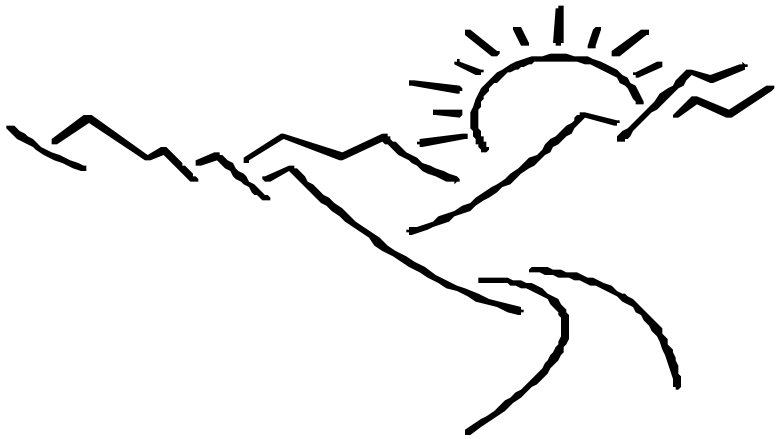
- Black light
- Eye dropper
- Sample bottles of rhodamine, fluorescein, and optical brightener

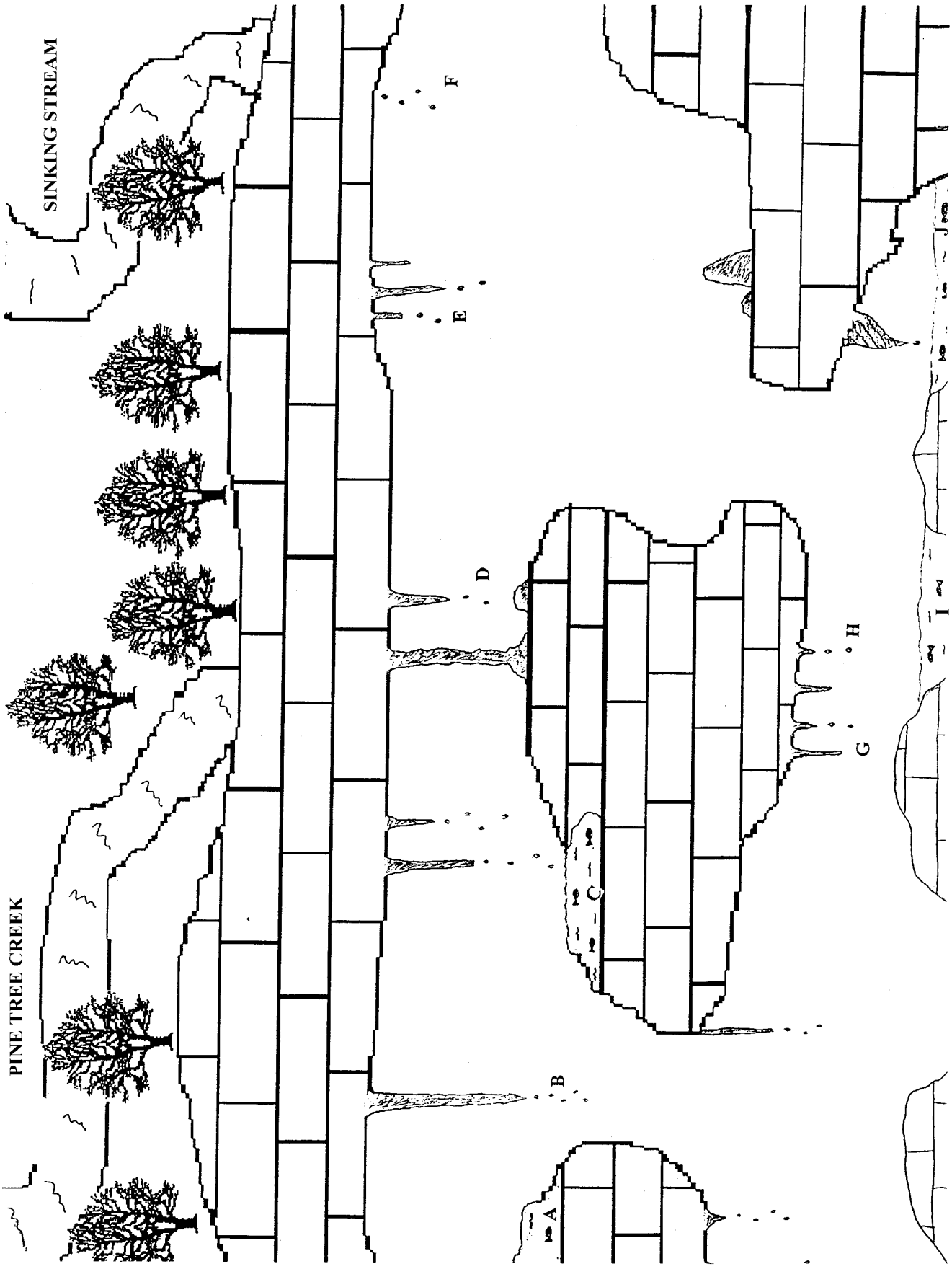
Procedure:

1. Ask the students to imagine that they have a delicate cave under their land. The cave has several large pools, and water drips from the ceiling in many places. A rare species of blind cavefish lives in several pools in the cave. Two streams run through their property and disappear into the ground in the woods behind their house. The water in one stream is very cloudy and may be polluted. Do the students think the water from the streams is entering the cave? How can they find out?
2. Discuss hydrologic dye tracing. Show the students examples of rhodamine and fluorescein, two types of dyes that are often used in dye traces. Stress that the dye is non-toxic and is used in very dilute concentrations.
3. The dye is fluorescent, and often an "optical brightener" (show students the sample bottle) is added to the dye to increase its fluorescence. Optical brightener is found in laundry detergents. It is the ingredient that makes your whites appear whiter and your brights appear brighter, by reflecting sunlight. Turn off the classroom lights and pull down the shades. Turn on the black light and walk around the room holding the brightener near students' clothes, demonstrating to each student that the optical brightener fluoresces. DO NOT SHINE THE BLACKLIGHT IN ANYONE'S EYES!
4. The students are going to use fluorescent dye to trace the streams into the cave. Have them determine how they will tell which stream is providing water to the different pools and drip sites in the cave. (They can put fluorescein in one stream and rhodamine in the other.)
5. How can the dye be detected once it enters the cave? In most cases, the dye will be so dilute that it will be invisible to the naked eye. The pools of water in the cave probably will not turn red or green. Can the fluorescence of the dye help in its detection? Tell the students that samples of the water are brought out of the cave and to the surface where they are tested in a fluorometer. A fluorometer can be used to detect very small quantities of fluorescent dye in solution. A fluorometer is a machine that detects the amount of light that passes through the water. The dyes will reflect light at different wavelengths, making it possible to detect fluorescein and rhodamine separately.
6. A fluorometer can detect even a few parts-per-billion of rhodamine or fluorescein. What does this mean? Tell the students that if they put a single drop of dye into a 50'x25'x4.5' swimming pool, they have a one part-per-billion solution. 3 drops yields a 3 ppb

solution. Certain dyes can only be detected in larger concentrations, such as a part-per-million. If you put one drop of dye into a 44-gallon barrel, you have a 1-ppm solution. You may wish to use an eyedropper to illustrate these concentrations.

7. Distribute copies of the attached worksheet. The students should color Sinking Stream green (representing fluorescein) and Pine Creek Stream red (representing rhodamine). Have the students use the data on the back of the worksheet to determine which pools and/or drip sites in the cave could be polluted. Why was testing done before the dye was injected? Discuss background levels of fluorescence. What might cause background levels? (Antifreeze [fluorescein makes it green; rhodamine makes it red] or laundry detergents [with optical brightners] or other chemicals that contain fluorescein or rhodamine would show up as background levels.) What seems to be the approximate background level of rhodamine in this case? Fluorescein? A positive dye concentration must be at least 3 times greater than the background level.
8. The students should color parts of the cave to illustrate the results of the dye trace. How do they think the water traveled through the limestone to reach particular sites in the cave? How long did the water take to reach the cave?
9. Have the students consider the following:
   - What effect will the polluted water have on the cave?
   - How can the pollution be cleaned up?
   - How can the students identify the source of the pollution?
   - How many other things could the pollutant be affecting?
   - Will the pollutants stay in the cave or will they have a farther-reaching effect?
   - What will this do to the wildlife in the cave?
10. Building on what the students have learned in previous activities, discuss:
    - what would happen if the limestone was covered with a layer of sandstone.
    - How long might the water take to reach the cave?
    - What effect will this have on the pollution?
    - What about the wildlife?
    - What about the cave in the future if the rock above is holding contaminants?
11. How can studies like this help the entire area in the future? Imagine real life place where dye tracing is taking place, places like Wind Cave National Park. By studying dye in the cave, what actions do you think will be made on the surface? Notice where the buildings are and where the water drains. Do you think information like this could help set limits of the numbers of people allowed to visit the cave? What about where they are able to park their vehicles? (Concerns about leaking oil, gas, antifreeze, or other pollutants.) What other benefits might come from a dye trace experiment?




SINKING STREAM
PINE TREE CREEK
A
B
C
D
E
F
G
H
I
J

Dye injected 4/2/99																				
	Rhodamine (ppb)										Fluorescein (ppb)									
Test Date	A	B	C	D	E	F	G	H	I	J	A	B	C	D	E	F	G	H	I	J
04/01/1999	0.00	0.02	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00
04/02/1999	0.00	0.01	0.01	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
04/03/1999	0.00	0.01	0.01	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
04/04/1999	0.00	0.92	0.00	0.00	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.04	0.00	0.00	0.00	0.00
04/05/1999	0.04	15.2	10.50	0.00	2.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	30.9	0.00	0.00	0.00	0.00
04/06/1999	7.60	22.0	18.0	0.01	12.7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	7.99	0.00	32.8	0.00	0.00	0.00	0.00
04/07/1999	10.0	19.8	35.7	0.00	18.2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.3	0.00	25.0	0.00	0.00	0.00	0.00
04/08/1999	10.2	3.05	28.8	0.01	6.45	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	19.4	0.01	3.07	0.01	0.00	0.00	0.00
04/09/1999	22.9	0.17	16.4	0.00	1.23	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.4	0.00	0.27	0.00	0.00	0.00	0.01
04/10/1999	20.2	0.03	17.1	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	1.52	0.00	0.00	0.00	0.00	0.00	0.00
04/11/1999	20.4	0.01	5.54	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
04/12/1999	19.6	0.00	0.05	0.01	0.00	0.00	0.09	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
04/13/1999	19.9	0.01	0.01	0.00	0.01	0.00	4.43	0.00	1.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
04/14/1999	15.4	0.01	0.00	0.00	0.01	0.00	13.1	0.01	6.98	0.09	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00
04/15/1999	8.02	0.00	0.00	0.01	0.00	0.00	15.0	0.00	7.07	1.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.46	0.01	0.00
04/16/1999	1.01	0.00	0.00	0.00	0.00	0.00	10.6	0.00	7.12	2.74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.22	0.00	0.00
04/17/1999	0.02	0.00	0.02	0.00	0.00	0.00	3.88	0.00	5.86	8.22	0.00	0.01	0.00	0.00	0.00	0.00	0.01	4.38	0.00	0.00
04/18/1999	0.00	0.00	0.00	0.00	0.00	0.00	2.09	0.01	2.99	4.47	0.01	0.00	0.00	0.00	0.00	0.00	0.00	4.33	1.88	0.01
04/19/1999	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	2.45	3.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.76	3.45	0.00
04/20/1999	0.00	0.02	0.00	0.00	0.01	0.00	0.01	0.00	1.09	1.26	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.82	2.02	0.00
04/21/1999	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.72	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	1.22	0.00
04/22/1999	0.01	0.01	0.00	0.00	0.01	0.00	0.01	0.01	0.03	0.09	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.00
04/23/1999	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
04/24/1999	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
04/25/1999	0.00	0.00	0.02	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00
04/26/1999	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01

WIND CAVE AREA MAP