# DESIGNING EFFECTIVE GROUND WATER TRACING STUDIES

[extract from pages 33-34 of Aley, 1999: "Ozark Underground Laboratory's Groundwater Tracing Handbook".]

As a summary to this handbook we have made a list of 11 basic rules for groundwater tracing studies; we call these

## "Rules to Dye By"

1. Successful groundwater tracing can be conducted in a wide range of hydrogeologic settings. Its utility is not confined to well developed karst aquifers. In mining situations pay special attention to the pH of the water. Bench tests of dye performance under the conditions to be encountered are often prudent.
2. Background sampling and quantitative analysis of the samples is an important component of most professional-grade groundwater traces. Many tracing investigations should have two or more rounds of background sampling prior to any dye introduction. The workplan for the study should allow the project manager to change the type and quantity of dyes based upon the results of background sampling.
3. In most cases fluorescein is the most effective groundwater tracing dye. Eosine and rhodamine WT are commonly very effective and can be used concurrently with fluorescein in many cases. To the extent feasible, if these three dyes are used concurrently, fluorescein should be used for the longest trace or the trace likely to encounter the most adsorptive surfaces. Rhodamine WT should be used for the shortest trace or the one likely to encounter the least adsorptive surfaces. There may be problem interference between fluorescein and eosine if the size of the fluorescence peak of one exceeds that of the other by more than two orders of magnitude. Interference between eosine and rhodamine WT can be a problem if the size of the fluorescence peak of one exceeds that of the other by more than three orders of magnitude. Note that these generalizations are based upon the size of the fluorescence peaks rather than the concentrations of the dyes.
4. Use enough dye, enough water, and dyes which are appropriate to the conditions likely to be encountered. There are no general equations which will give you these values. One seldom recovers most of the dye introduced because of losses to adsorption, biological decomposition, and other processes. "Enough dye" is a function of the type of dye, the type of dye introduction point, characteristics of the aquifer, the nature of sampling stations, the type of sampling conducted, and the effectiveness of adsorption along the flow routes to be traversed by the dye. "Enough water" may be controlled by the nature of the study or by logistics; try to use as much as is reasonably possible.
5. Use dye introduction points which are appropriate to the questions to be addressed by the investigation. Utilize monitoring wells for dye introduction only when they are clearly appropriate.
6. Sample all the points at which the dye might discharge; if you don't sample you don't know. Do thorough field work prior to dye introduction. Don't just sample monitoring wells if you need to assess off-site migration. Groundwater discharge may occur at obscured points in stream channels; sample the streams at appropriate intervals. Sample all of the monitoring wells; reality may or may not fit the site model, and knowing where dyes were not detected can be valuable information.

7. Sample for an adequate period of time. One approach for dealing with sampling duration is to recognize that tracer dyes are most effective in assessing preferential flow routes. Such flow routes provide relatively rapid water and dye transport; if such routes exist between the dye introduction point and sampling stations then one should be able to estimate that one or more dye recoveries should occur prior to the end of a projected study period. Failure to recover the dye in that period should be viewed as evidence that the hypothetical preferential flow routes either do not exist or else are not integrated into a preferential flow system. ASTM Standard D-5717-95 provides data on typical groundwater velocities in karst aquifers as a function of the scale of measurement. We have found these data useful in carboriate rock terrains for addressing issues of dye tracing study duration.

8. For most studies, primary reliance should be on sampling with activated carbon samplers and secondary reliance on grab samples of water. The use of both kinds of samples should be considered and will often enhance the value of the investigation. Samplers must actually be in the water in order to sample it; sloppy sampling by those who are not willing to get wet or dirty in the field is the bane of dye tracing studies. When dealing with springs, never assume that nearby springs (even those only a few feet apart) are receiving waters from identical areas.

9. Collect samplers and place new samplers at intervals frequent enough to insure that dyes are not missed and that most or all of the dye recovered at a sampling station is not limited to only one sampling period. In most cases weekly intervals are adequate; more frequent sampling can be desirable during the first week or two after dye introduction. Similar sampling intervals during a study are often desirable.

10. Good analysis for the tracer dyes is essential for professional groundwater tracing. In most cases this means analysis by a spectrofluorophotometer operated under a synchronous scan protocol. The study must establish credible detection thresholds for the various dyes based upon the analytical instrument, field experience, and site-specific background sampling. Detection thresholds should be neither too high nor too low.

11. Groundwater tracing is a bit like brain surgery. It is fundamentally simple, yet most patients (clients) would hope that the person doing the work has experience. We are always happy to answer questions about dye tracing and to design a groundwater tracing program for you or help you design one. We have experience from about 3,500 successful groundwater traces; please call on us.



Ozark Underground Laboratory

1572 Aley Lane • Protem, MO 65733

phone: (417) 785-4289 • fax: (417) 785-4290 • e-mail: OUL@Tri-Lakes.Net