TRACER-DYE STUDY
GUIDELINES

Water Quality Branch
Standards and Approvals Division
Alberta Environment
December, 1991

1.0 INTRODUCTION

This document is to be used as guidance, in applying for and conducting a tracer-dye study. Tracer-dye studies, simply explained, are studies which involve injecting a dye at some location in the stream and measuring the resulting response, or dye cloud, at other locations downstream to determine the time of travel and the dispersion characteristics of the stream. Time of travel refers to the time of movement of water or waterborne materials from one point in a stream to another.

Tracer dye studies can be of immense assistance in assessing and formulating solutions to environmental problems. Data from such studies enable those charged with public safety to predict the rate of movement, the duration, and the magnitude of pollutant concentration that can result from the accidental spill of an objectional material, or the controlled release of the contents of a holding pond or other containment.

Although the focus of these guidelines is on tracer-dye studies conducted in rivers and streams, this shall not be interpreted to mean that tracer-dye studies in lakes, reservoirs, groundwater, or any other water-body are exempt. Proponents who wish to conduct tracer-dye studies involving any water-body must submit an application for the approval of such studies.

2.0 APPLICATION FOR PERMISSION TO CONDUCT A TRACER-DYE STUDY

In accordance with Section 11 of the Clean Water (General) Regulations, written permission must be obtained from the Director of Standards and Approvals before commencing a tracer-dye study. To apply for this permission, the following information must be submitted to the Director of Standards and Approvals.

(a) A letter outlining the study which includes:

  (i) the name and address of the proponent applying to conduct the study;

(ii) the purpose of the study;
(iii) the river reach in which the study is to be conducted;
(iv) the type of dye to be used, its concentration, and the volume of dye to be used in the study;
(v) the time interval over which the actual testing, i.e. dye injections and sampling, is to take place; and
(vi) the name and address of all licenced water-withdrawal users in the Mixing zone in the river to be studied.

Information on who the licenced water-withdrawal users are may be obtained from the Water Resources Administration Division of Alberta Environment.

(b) A location map outlining the watershed boundary and depicting the river reach in which the study is to take place.

(c) A 1:50,000 topographic map on which shall be indicated:

(i) the river reach to be studied;
(ii) all water-users' withdrawal points in the study reach;
(iii) proposed dye injection points; and
(iv) proposed dye sampling points.

Topographic maps may be obtained from the Land Information Services Division of Alberta Forestry, Lands and Wildlife.

(d) Information pertaining to the river flow and its hydraulic characteristics at the proposed dye-injection points, specifically

(i) the historical monthly average flow in the study reach for the period of study;

(ii) the 1-in-10 year low flow of 30 days duration (30Q10) in the study reach for the period of study;

(iii) where possible, the hydraulic characteristics of the river in the study reach - its mean width, depth, velocity, and water-surface slope - for the period of study; and

(iv) an estimate of the projected average river flow for the period of study.

(e) If any tracer other than Rhodamine WT is to be used, the following additional information must be submitted:

(i) the reason why Rhodamine WT is not adequate as the study dye;

(ii) short-term toxicity information on the proposed tracer, LC_{50} and/or LD_{50};

(iii) long-term toxicity information on the proposed tracer, preferably from microcosm experiments using 1/50th to 1/100th of the LC_{50} concentration for 90 days or longer;

(iv) any available carcinogenicity and mutagenicity data;

(v) any available environmental chemistry data, sorption, volatility, bioconcentration, etc.; and

(vi) any other information required by the Director of Standards and Approvals.

(f) An estimate of the distance from the point where the dye is injected to the point of complete mixing, i.e. the mixing zone. See Section 3.0 STUDY CONSIDERATIONS for further information.

(g) Contingency plans in the event of a dye spill.

Note, applications to the Director shall be submitted at least 30 days prior to the commencement of any dye study.

3.0 STUDY CONSIDERATIONS

At no time after the point of complete mixing, or at any water-user withdrawal point within the mixing zone, shall the concentration of the dye, Rhodamine WT, exceed the latest National Sanitation Foundation (NSF) drinking water standard. Water-user withdrawal points are deemed to include, but are not limited to, potable water supply intakes, livestock watering points, or irrigation withdrawal points.

Unless otherwise specified by Alberta Environment, the length of the mixing zone shall be estimated by the following formulas:

- for a single point midchannel injection (continuous or slug)

$$L_m = 0.2 \frac{UW^2}{eZ} \quad \text{.... (1)}$$

where

L_m is the length of the mixing zone, in metres;

e_Z is the transverse dispersion coefficient, in metres squared per second, given by

$$K_Z = \frac{eZ}{dU^*} \quad \text{where} \quad \text{.... (2)}$$

$K_Z = 0.237 + 0.001$ (W/d) for Sn ≤ 1.2

$K_Z = C + 0.0017$ (W/d) for Sn > 1.2

where C = 3.1 (Sn) - 3.30

U^* is the shear velocity, in metres per second, given by $U^* = (gdS)^{½}$;

K_Z is a dimensionless coefficient;

U is the mean velocity, in metres per second;

W is the average channel width, in metres;

d is the mean depth, in metres;

g is the acceleration due to gravity (9.8 m/s^2);

S is the water-surface slope in metres per metre;

Sn is the sinuosity of the river; and

C is a dimensionless constant.

- for a single-point side-bank injection (continuous or slug)

$$L_m = 0.4 \frac{UW^2}{eZ} \quad \text{.... (3)}$$

Equations (1) and (3) are dimensionally correct and may be used with units other than those of the SI system, such as foot-pound units, if done consistently.

Multiple point injections and line injections are not considered here for a number of reasons: (1) very few Alberta rivers are wide enough to warrant multiple point injections; and (2) line injections have been used in attempts to approximate line diffusers, but the practical considerations of releasing a tracer at a constant rate from a boat which travels at constant speed across the river does not correspond very well to the normally assumed mathematical condition used in subsequent calculations, i.e. constant initial concentration across the stream cross-sectional area. Even where a tracer is released at a constant rate from a boat crossing the river at a constant speed, the concentration will not be uniform, it will be higher in the shallower parts of the river. Sometimes a line injection has been used on the mistaken assumption that the mixing zone is significantly shorter for a line source than a point source.

To ensure that the dye used does not collect in areas of calm or stagnant water, dye injections should not be made in shallow or stagnant regions of the river. As a rule, dye should be injected in only about the central 75 percent of the flow, i.e. side injections should take place at the periphery of the central 75 percent of the flow.

At temperatures above 5°C, injections can be made by pouring a measured amount of dye into the central 75 percent of the flow. At low temperatures surface tension effects play an increasing role in the dispersion of the dye causing it to spread across the surface of the river rather than to disperse it downwards and out. In

instances where Rhodamine WT has been poured into the river at temperatures below 5°C, the dye has coloured the river an alarming red for a number of kilometres downstream. Therefore, at and below 5°C all dye injections shall be subsurface injections.

The specific gravity of Rhodamine WT is approximately 1.19, therefore, dilution is necessary to ensure that the dye added is neutrally bouyant with respect to the water to which it is added. It is recommended that Rhodamine WT be diluted with an equal volume of methanol (specific gravity 0.79) in order to produce a neutrally buoyant mixture with lower viscosity and surface tension characteristics.

4.0 PUBLIC INVOLVEMENT

By the nature of a dye-tracer study the dye will be highly visible immediately after injection and could generate negative public reaction if the public is unaware of the purpose of the study, or the measures adopted to protect their interests, and the environment in general. To ensure public awareness and co-operation, the Director of Standards and Approvals may require anyone or any company planning a tracer-dye study to hold public meetings and advertise those meetings. The purpose of these meetings will be to answer any questions the public may have concerning the study.

Upon receiving approval to conduct a tracer-dye study, the proponent shall be responsible for:

(a) informing all licenced water-withdrawal users in the river reach under study, at least 7 days prior to commencement of testing, of:

(i) the date(s) the test(s) will be conducted on,

For water treatment plants:

(ii) the approximate time at which the peak concentration of the dye will pass the withdrawal point, and

(iii) the anticipated peak concentration;

(b) the proponent shall notify the Director of Pollution Control at least 48 hours in advance of any tests conducted, of:

(i) the location of each injection site,
(ii) the quantity of dye to be injected at each site,
(iii) the times of injection,
(iv) the means of injection,
(v) the location of each sampling site, and
(vi) a sampling schedule at each sampling site giving the starting time, the sampling frequencies and the completion time; and

(c) in the event a test is cancelled, the proponent shall, at the earliest opportunity, inform all licenced water-withdrawal users and the Director of Pollution Control of the cancellation using the most-immediate form of communication, and of any changes that will be made in the test schedule as a result of the cancellation.

5.0 REPORTING

No later than three months after Approval expiry, the proponent shall submit a report on the tracer-dye study to the Director of Standards and Approvals, with a copy sent to the River Engineering Branch of Alberta Environment, containing:

(a) information on any cross-sectional surveys completed at the injection and downstream measuring sites. (The surveys should cover the channel from the top of the bank on each side, and show the bed and bank levels with respect to the water surface elevation on the day of the survey. It would be preferable if these were tied into a common datum, but the distances involved between measuring stations may preclude this.);

(b) if the tests are conducted under winter conditions, the ice thickness at each cross-section survey site;

(c) a plan and/or table summarizing the cross section locations and distances along the river between cross-sections;

(d) velocity of flow measurement across each cross-section;

(e) the discharge in the river at the time of measurements;

(f) the measurements of the dye cloud as it passes the measuring station (time, concentration, location across the cross-section, etc.); and

(g) any other information required by the Director of Standards and Approvals.

The above data must be submitted in tabular form, but may be supplemented by graphical form.

The reports will be kept on file with Alberta Environment to answer any questions that might arise from the use of tracers, and to develop a database accessible to members of the general public, as well as public and private organizations.

Suggested References

1. Beltaos, S. 1978. "Transverse Mixing in Natural Streams". Report SW-78/01. Transportation and Surface Water Engineering Division, Alberta Research Council, Edmonton, Alberta.

2. Hubbard, A., et al., "Measurement of Time of Travel and Dispersion in Streams by Dye Tracing". Techniques of Water Resources Investigations of the United States Geological Survey, Chapter A9 (no date).

3. Fischer, H.B., et al., "Mixing in Inland and Coaster Waters". Academic Press, New York, New York, 1979.

4. Turner Designs, Fluorometric Facts: "Flow Measurement". Mountain View, CA (no date).

5. Turner Designs, Fluorometric Facts: "Circulation, Dispersion and Plume Studies". Mountain View, CA (no date).

6. Wilson, James, F., et al., "Fluorometric Procedures for Dye Tracing". Techniques of Water Resources Investigations of the United States Geological Survey, Chapter A12, 1986.

7. Kellerhals, R., C.R. Neill, D.J. Brag, "Hydraulic and Geomorphic Characteristics of Rivers in Alberta". River Engineering and Surface Hydrology Report 72-1. Research Council of Alberta, Edmonton, Alberta, 1972.

8. Fonstad, G.D. and M.E. Quazi, (1986), "Final Report, Transverse Mixing Analyses in Natural Streams", River Engineering Branch, Technical Services Division, Alberta Environment, Edmonton.