Study of accidental rejects on the Tarn River (France)

V. Rosales-Sierra[1*] and C. García-Govea[2]

[1]*Fluidyn, 7 Bld de la Libération 93200 Saint-Denis France. +33 142431666 victor.rosales@fluidyn.com*
[2]*CNRS Laboratoire de Géographie Physique, Meudon Cedex, France. Tel:+33 145075583 coral.garcia@cnrs-bellevue.fr*

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Estudio de emisiones accidentales sobre el Río Tarn (Francia)

Abstract

A methodology to forecast river-pollution scenarios in case of accident was implemented for the Tarn River in the south of France. Field information about diffusion transport was sampled in different river discharge conditions by the use of two kinds of tracers: Rhodamine and Fluorescein. Numerical simulations were later implemented to reproduce additional scenarios. In this communication we would like to show the difficulties encountered in this study with the aim to improve in the selection of sample points for tracer campaigns and in the selection of numerical models for a realistic agreement with available information. Uncertainty in field information will influence the calibration phase in numerical models and by consequence the quality of the forecast.

Keywords: water pollution, numerical simulation, tracer, calibration

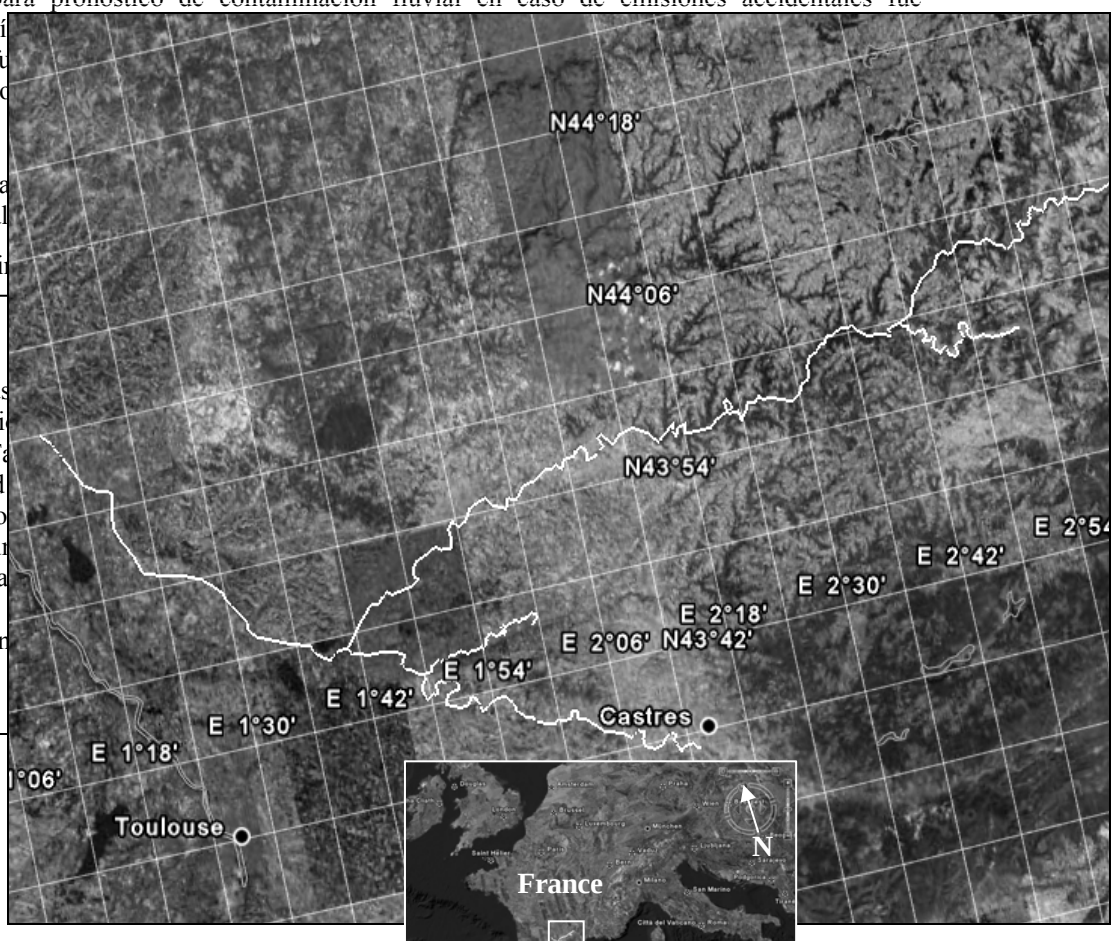
Resumen

Una metodología para pronóstico de contaminación fluvial en caso de emisiones accidentales fue implementada para el Rí
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Introduction

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* Autor de correspondencia
E-mail: victor.rosales@free.fr

combination of tracer campaigns and numerical simulations is a major challenge to take into account field sampling and to reduce costs. The procedure intends to reach acceptable uncertainty in forecasts. In this communication we expose the procedure applied to the Tarn river project and discuss the main difficulties encountered in this experience.

Methodology

Field tracer campaigns

A detailed analysis of the terrain is necessary to consider the main obstacles along the watercourse and to detect important changes in geomorphology. These elements modify the flow and by consequence the transport of tracers.

The study area was divided into 8 sections by the EATC Cabinet (2006) (Fig. 2). The study zone covers more than 350 km and includes the main Tarn River from Millau to Montauban and 3 secondary tributaries: Dourdou, Agout and Dadou. The length of the sections was calculated bearing in mind, on one hand, to avoid too low concentrations in larger distances; and on the other hand, to respect the limits of the 4 municipal departments of the zone (82 Tarn-Garonne, 81 Tarn, 12 Aveyron, 31 Haute Garonne).

In order to incorporate a wide range of river discharges three field tracer campaigns were considered: low water conditions, middle water conditions and high water (flood) conditions. Discharge information was obtained from the French Regional environmental directions (DIREN) corresponding to the period between the years 1970 to 2000 (table 1, Fig. 2).

The mass injected in each campaign was variable between 50 and 140 kg of one of the following substances: Rhodamine or Fluorescein. Both of the substances have physical and chemical neutral properties. The former one is cheaper but needs a special treatment, described by Byrappa et al. (2006), to reduce residual waste by carbon or ozone filters. The second one can be more expensive since a higher quantity, compared to Rhodamine, is needed to balance mass lost caused by UV rays and crystallisation of this tracer as described by CTG (2002).

The selection of sample points needs careful consideration to locate them upstream of important obstacles like bridges, dams, confluence with other tributaries or to locate them at the river banks and river centre in case of sharp bends (Fig. 3). Dams and bridges play a complex role depending on their size and dam discharge, the lack of information about important obstacles generates great uncertainty and makes the validation of further numerical models impossible to achieve. Finally,

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Table 1. Selected discharge conditions ($m^3 s^{-1}$).

Tributary	Station	High (decennial)	Middle	Low
Agout	Lavaur	630	39	3,6
Tarn	Pécotte	1400	86	12
Tarn	Villemur	1800	152	21

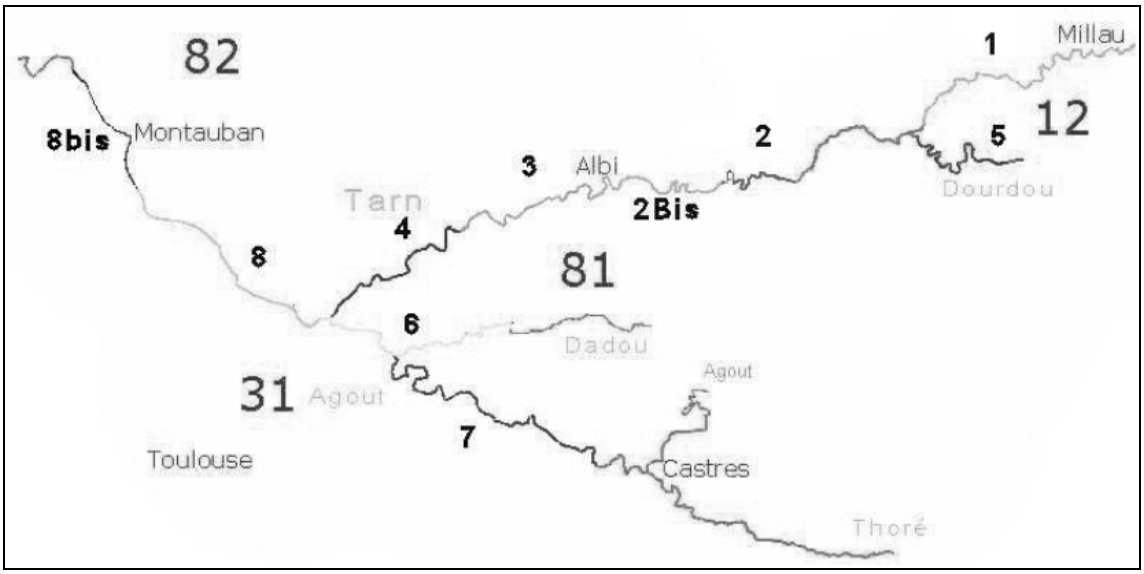


Figure 2. Division of the study area (EATC).

special care must be taken in the short distance between the reject point and the well-mixed point where the tracer concentration is non-homogeneous thus the sampling is extremely uncertain. This distance varies according to the river discharge. For example, high water discharge implies better mixing thus shorter distance to homogenize the substance into the water.

The characteristics of the sampled curve are shown in Fig. 4. The invisible front is detected by laboratory analysis of samples when the concentration exceeds 0,1 μg l^{-1}, the visible front is the beginning of the colouring on the water detected by human eye on the field, the peak is the maximum concentration found by laboratory analysis, the visible trail is the end of the colouring on the water detected by human eye on the field and the invisible trail is detected by laboratory analysis when concentrations drop under 5 or 1 μg l^{-1} depending on field conditions.

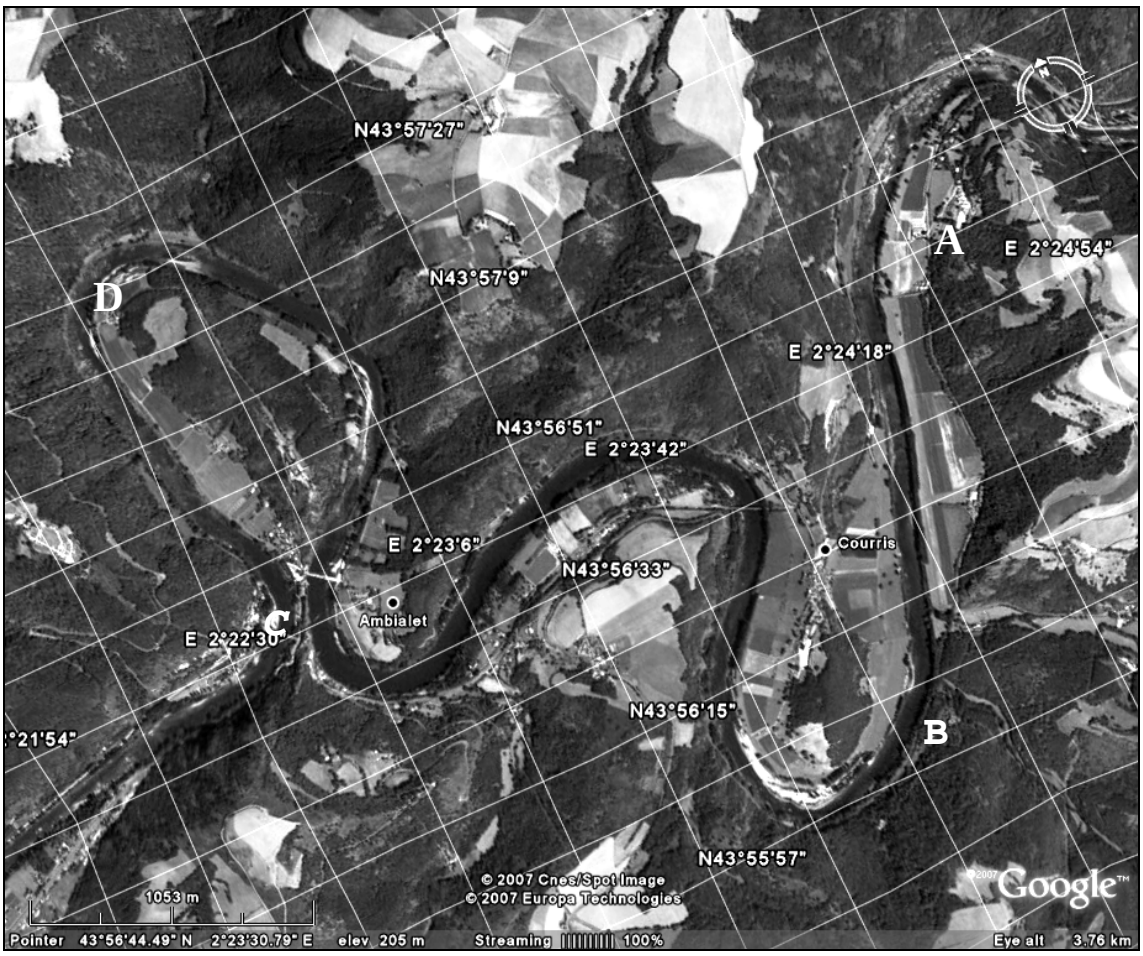


Figure 3. Selection of sample points in Section 2. (A) Reject point, (B) well mixed point, (C) Intermittent discharge damp, (D) Sharp bend.

Numerical simulations

Numerical tools reduce the cost of accidental pollution simulations compared to tracer campaigns. Nevertheless, numerical simulations can only be a complementary due to high uncertainty in numerical models and the unavoidable calibration phase. A detailed topo-bathymetry is essential for an acceptable representation of the numerical model in particular near the zones of noticeable varying space gradients (change of slope, diminution/growth of hydraulic area, strong bends,

islands).

The number of cross-river profiles should be adequate to represent the river geomorphology. From Fig. 5 and 6, a greater number of cross-river sections is required between the points B and C than between points A and B in order to better represent the abrupt changes in the riverbed and avoid unrealistic simplifications.

The choice of the model dimension depends on available topo-bathymetric information and the size of the domain. As the horizontal ratio of the river (length/wide) increases, the results of a coarse 2D model can be as uncertain as 1D models. One solution to avoid lose of precision is to divide the model into stretches but this solution cuts the continuity of the flow and limits the simulation to the corresponding stretch. In this study that solution was applied taking into account that the objective was to compute accidental rejects to alert downstream locations in the short time. In farther locations, authorities should have enough time to detect pollution by direct sampling of the water flow.

Validation of numerical simulations

The numerical simulations were carried out with the Fluidyn 3D NS (Navier Stokes) finite volumes code that was validated for fluid and structure mechanics by Patil et al. (2001). The models were built using curvilinear structured volumes. A hydrodynamic computation was first launched to obtain a steady state flow. The dispersion computation was then initiated to simulate the transport of the tracer according to the procedure of Transoft (2005). An iterative method is used to get a validated solution. The validation of the numerical simulations is made by comparison with tracer curves considering uncertainties in field sampling and numerical methods in agreement with the validation method of Rosales and Levacher, (2004). Important differences in points of comparison correspond to uncertainties, which were found systematically in points between the reject point and well-mixed point (ex. A and B in Fig. 3).

Fig. 7 shows the differences found between three curves sampled at the centre, left bank and right bank of the same well-mixed point. This point was evidently erroneously chosen because the well-mixed condition is not achieved at this point.

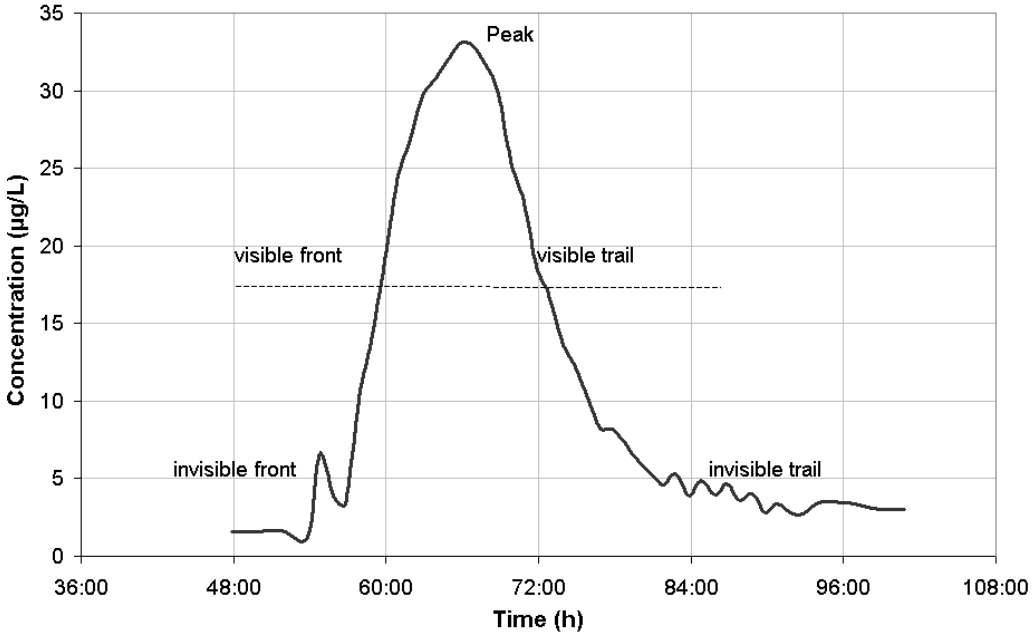


Figure 4. Characterization of tracer curves.



Figure 5. Cross-river profiles location (section 8).

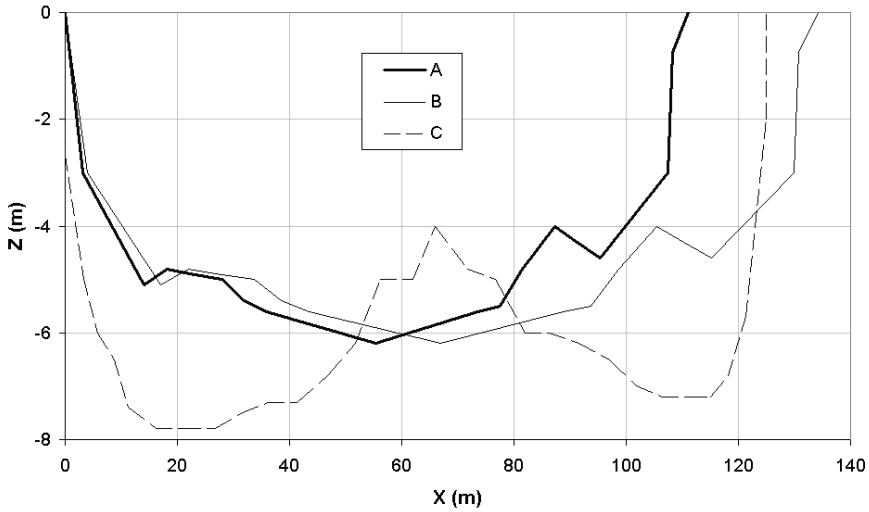


Figure 6. Cross-river profiles (Section 8).

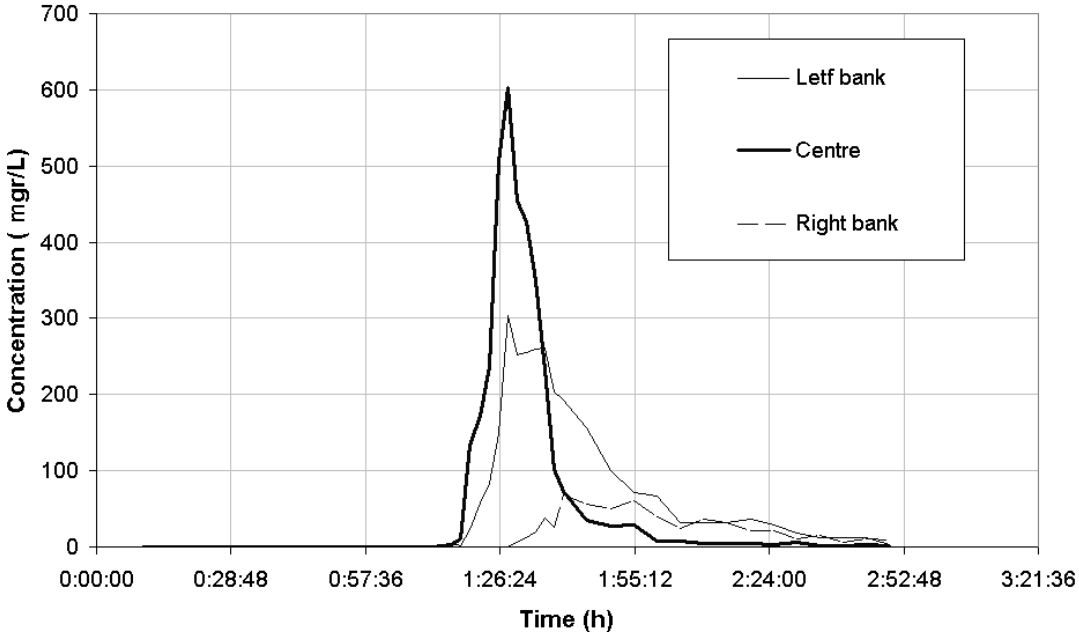


Figure 7. Samples in the well-mixed point (section 8).

These kinds of uncertainties are due to insufficient distance from the injection point or lack of care in tracing campaigns. Important uncertainties are also found in points just downstream of obstacles or tributary confluences. In these cases the uncertainty comes from the field data produced by complex hydrodynamics or random variations in tracer samples at chaotic zones. Other errors or differences should be due to incorrect or insufficient topo-bathymetry data or numerical model errors.

An example of unsuccessful calibration is show in Fig. 8 because the difference in field and numerical results has no coherent reason to exist; then, such an important uncertainty can be expected randomly, in particular when considering the sample point in Fig. 8. In this case the difference might be due to a bad representation of the geomorphology (lack of sufficient data) or numerical errors.

An example of successful calibration is show in Fig. 9. Despite the differences in field and numerical results, the uncertainty is reasonable in the well-mixed point and in the point downstream the Aveyron confluence. The uncertainty is due to complex hydrodynamics and random diffusion in these zones; apart from that, the representation of the bed slope was made with more precision in this section thanks to a more important density of cross-river profiles according to Transoft (2007).

Results and discussion

The tracer campaigns suffered a mayor drawback due to operational logistics and economy. In fact, sampling was limited to potable water intakes and to well-mixed points without considering sampling around mayor obstacles along the river; this meant only 2 or 3 sampling points along one division. Another problem was the limited information of topo-bathymetry; only from 3 to 6 cross-river profiles were used to reproduce divisions of up to 50 km, which correspond to 1 cross-river profile representing the characteristics of 10 km topo-bathymetric riverbed.

Consequently, numerical simulations were indeed difficult to set up. The first controversy in numerical simulation was the futility of applying a 3D code with limited input data. In fact, coarse topo-bathymetric simplifications vanishes the utility of a 3D analysis considering the lack of precision in terrain representation. Only few zones of the numerical models had a valid 3D behaviour when

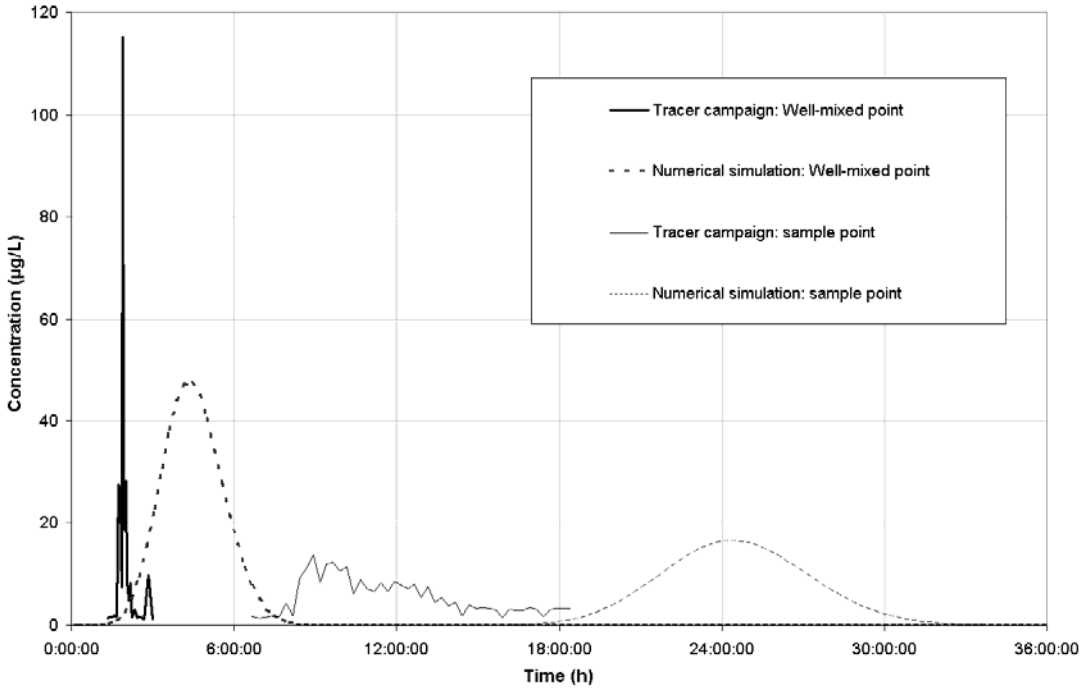


Figure 8. Unsuccessful calibration (Section 2).

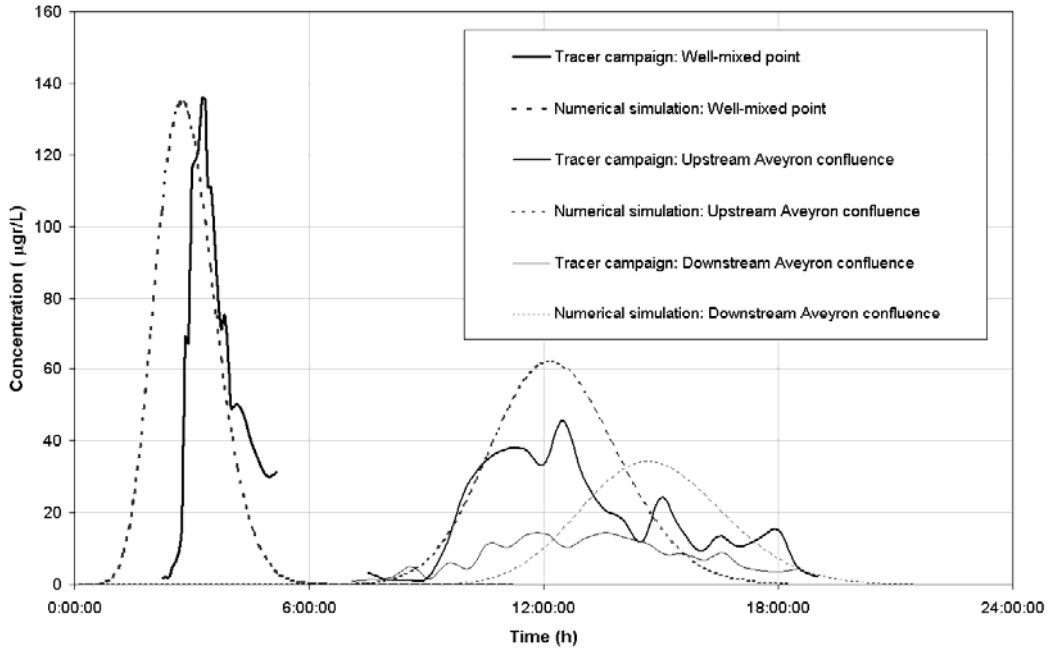


Figure 9. Successful calibration (Section 8bis).

sufficient topo-bathymetric data and tracer campaigns information was found: only one or two divisions of the river.

The end result was the incapacity to represent the physics of the Tarn River with precision in complex numerical models and a waste of time in the iterative process to get an acceptable calibration. 2 of the 8 divisions (1, 2 and 2bis in fig. 2) failed to accomplish the calibration and therefore were excluded from the final results. These divisions have the distinctiveness of being in the highlands of the Tarn River where the terrain characteristics are more irregular than in the valley zone where the rest of the divisions are located.

Finding a compromise between cost and precision is then the real challenge in future projects. From this experience we considered it important to sample more points especially upstream of the main obstacles like river confluences, dams or any other zone with observable changes to the flow. To reduce costs, visual sampling can be enough in the beginning of the tracer length, where the concentration is high enough to be observed by human eye.

Another important point is to perfection the iterative numerical methods. The dimension of the model has to be in agreement with the available data. 3D computations involve sufficient topo-bathymetric data to reproduce 3D flow with precision. Coarse simplifications entail then a simpler 2D or 1D model to avoid further numerical problems.

Alas, a numerical model won't compensate the lack of terrain information.

Conclusions

A methodology to forecast pollution scenarios was implemented for rapid response on accidental events by tracer campaigns and numerical simulations. Specialists need to follow a strict methodology to provide quality results. Users and engineers can take advantage of this methodology. Improvement in data acquisition and selection of numerical tools are necessary to reduce uncertainty, time and costs.

The development of an interpolation tool for validated scenarios is the next step to answer to the condition of fast response in case of accidental reject.

Acknowledgments

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