UNDP/GEF Danube Regional Project

Strengthening the Implementation Capacities for Nutrient Reduction and Transboundary Cooperation in the Danube River Basin

Development and maintenance of the DBAM

Project Component 2.3-4: Final Report

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I Introduction

1.1 UNDP/GEF Danube Regional Project

The UNDP/GEF Danube Regional Project started in 2001 with the long-term development objective to contribute to sustainable human development in the Danube River Basin through reinforcing the capacities of the participating countries in developing effective mechanisms for regional co-operation and co-ordination in order to ensure protection of international waters, sustainable management of natural resources and biodiversity. In this context, the Project supports the ICPDR, its structures and the participating countries in order to ensure an integrated and coherent implementation of the Strategic Action Plan 1994 (SAP 1994), the Common Platform and the forthcoming Joint Action Plan and the related investment programmes in line with the objectives of the Danube River Protection Convention (DRPC).

The overall objective of the Danube Regional Project is to complement the activities of the International Commission for the Protection of the Danube River basin (ICPDR) required to provide a regional approach and global significance to the development of national policies and legislation and the definition of priority actions for nutrient reduction and pollution control with particular attention to achieving sustainable trans-boundary ecological effects within the Danube river basin and the Black Sea area.

One of the immediate objectives is Capacity building and reinforcement of trans-boundary co-operation for the improvement of water quality and environmental standards in the Danube river basin. In view of this objective, Phase 1 of the Project comprises a component directed towards the Improvement of procedures and tools for accidental emergency response with particular attention to trans-boundary emergency situations (Project Output 2.3).

In the remainder of this document the UNDP/GEF Danube Regional Project will be referred to as "the Project".

1.2 Development and maintenance of the DBAM

The Danube Basin Alarm Model (DBAM) is an operational model for the simulation of the transport and decay of substances that have been released during accidental spills. The model forms an integral part of the Danube Accident Emergency Warning System (AEWS) in operation in the Danube River Basin, and supports the assessment of the consequences of accidental spills for the river water users. See Figure 1-1.

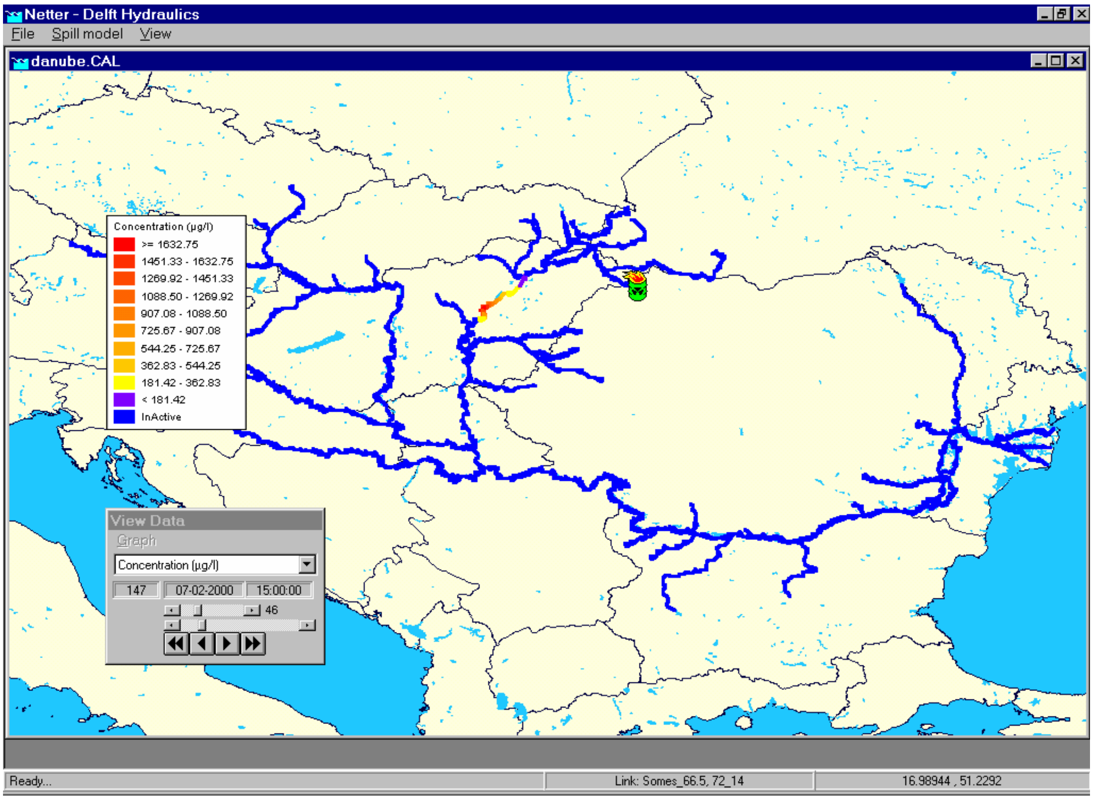

Figure 1-1: Application of the Danube Basin Alarm Model to the cyanide incident in the Tisa river (January 2000).

The DBAM model-system is used by the Principal International Alert Centres (PIACs) of the Danube AEWS as a tool to evaluate the possible impacts of a trans-boundary water pollution incident. First of all the DBAM is aimed to assess the expected concentration of a pollution plume and its time of arrival at a particular river section downstream.

The experience from the last accidental pollution events indicates that the AEWS and in particular DBAM needs substantial improvement to become a satisfactory tool for adequate management of trans-boundary contamination from catastrophic events.

In this context, part of the Project Output 2.3: "Improvement of procedures and tools for accident and emergency response with particular attention to trans-boundary emergency solutions", is focused on the maintenance and calibration of the Danube Basin Alarm Model (Activity 2.3-4).

1.3 The current report

A specific Inception Report describes the activities of the International Consultant in relation to the planned outputs under Activity 2.3-4 of the Project (WL | Delft Hydraulics, 2002). The general objective for the work done by the International Consultant is:

> *To provide a technically sound basis for the DBAM calibration (during Phase 2 of the Project) and for the future use of the model.*

The present document constitutes the Final Report of these activities. It starts with a brief description of the Danube Basin Alarm Model (Chapter 2). Next, a review of existing information is presented (Chapter 3). Chapter 4 presents a short study, which analyses the different options for the calibration of the model. This study results in alternative approaches towards the calibration, which are clearly laid out for discussion with the ICPDR (APC/EG) and the Project staff in a dedicated Work Shop (held in Ljubljana on 8-9 September 2003). Implications for the use and maintenance of the model are taken into consideration.

Chapter 5 continues with some information regarding the preparation of the Workshop mentioned above, while Chapter 6 discusses the results from the Workshop.

Chapter 6 in particular together with the annexes to this report constitute a specification for and boundary conditions to the activities to be carried out during Phase 2 of the Danube Regional Project.

1.4 Acknowledgements

The Consultant acknowledges the co-operation of the DRP project staff, the ICPDR Secretariat staff as well as the APC/EG members. Furthermore, we express our appreciation for the contribution of Dipl.-Ing. Werner Blohm (Institut für Hygiene und Umwelt, Hamburg) to the Workshop, in relation to the Elbe alarm model ALAMO.

2 Brief description of the model

2.1 General

The Danube Basin Alarm Model aims at predicting the travel time of and the concentration in a cloud of pollutants released in the river system as the result of an accidental spill. The focus is on large scale events of a trans-boundary nature. The model is intended to be used for a first and rapid assessment under operational conditions: the run-time should be short and the necessary input data should be limited.

In view of the requirements above, a 1-dimensional approach has been selected: the variation of the concentration *along* the Danube and its main tributaries is calculated. The cloud of pollutants is supposed to be well mixed over the conveying part of the river cross-section.

Following the example of other large European rivers, the so-called "dead zone model" was adopted. This model includes two major physical phenomena: (1) the transport of the cloud of pollutants as a whole in a downstream direction by the river flow, and (2) the mixing and dilution of the cloud. An important aspect of the latter phenomenon is the mixing of water between the main stream of the river and (semi-)stagnant parts of the river cross-section or "dead zones".

2.2 Mathematical description

The governing mathematical equations of the dead zone model are:

$$\begin{aligned} &\frac{\partial C}{\partial t} + U\frac{\partial C}{\partial x} - D\frac{\partial^2 C}{\partial x^2} = -\beta e\left(C - C_s\right) \\ &\frac{\partial C_s}{\partial t} = e\left(C - C_s\right) \end{aligned} \qquad (1)$$

Where:

C	concentration in the main stream (g/m^3)
C_s	concentration in the dead zone (g/m^3)
U	mean flow velocity (over the main stream) (m/s)
D	longitudinal dispersion coefficient in the main stream (m^2/s)
e	mass transfer coefficient between the dead zones and the main stream (/s)
β	ratio between the cross section of the dead zone and the cross section of the main stream (-)

For reasons of efficiency and accuracy, an *analytical solution technique* is used. This provides a solution in a closed mathematical formula for a given location x at a given time t, as a result of a spill of a mass M (g) at location x = 0 at time t = 0:

$$c(x,t) = \frac{M\ /\ Q}{\sqrt{4\ \pi\ D\ t/u_{xc}^2}} \times \left[\exp\left[\ -\frac{(\ t\ -\ x/u_{xc}\ )^2}{4\ D\ t/u_{xc}^2}\ \right] \right] \left[1 + \frac{G_t}{6} H_3\left(\frac{t\ -\ x/u_{xc}}{\sqrt{2\ D\ t/u_{xc}^2}} \right) \right] \qquad (2)$$

Where:

$$u_{xc} = \frac{U}{1+\beta}$$

$$D = \alpha \frac{U^2 W^2}{h\, u_*}$$

(Semi-empiric after Fisher)

Q	river discharge (m^3/s)
$H_3(z)$	3rd Hermite polynomial (= $z^3 - 3z$)
G_t	skewness coefficient (-)
W	river width (m)
h	river depth (m)
u_*	shear stress velocity (m/s)
α	constant of proportionality (-)

The parameters α (longitudinal dispersion) and β (dead zones) are the main calibration parameters.

The solution mentioned above is extended with a factor accounting for the decay of the spilt pollutant:

$$c(x,t) = c_{without\ decay}(x,t) \times \exp(-kt) \qquad (3)$$

Where:

k decay rate (1/s)

The “dead zone model” is commonly accepted as a basis for spill models in river systems: the same mathematical model is used in the Rhine basin, the Elbe basin and for several rivers in France. It should be noted however, that there are other ways to solve the mathematical equations. The Elbe model for example uses a numerical approach, whereas in France the so called “mixing cell” method is used. The different solution techniques do not have significant implications with respect to the potential model accuracy and the calibration method (supposing that the implementation is done properly).

2.3 Implementation

The equations (1) and (2) mentioned above are valid for a uniform river stretch with constant flow characteristics. For the practical application to the Danube river and its main tributaries (see Figure 1-1), the solution has been expanded for confluences and bifurcations, taking into account the spatial variability of the hydraulic characteristics of the river system.

The actual calculation procedure consists of two steps:

1. The calculation of the hydraulic coefficients (discharge Q(x) and velocity U(x)).
2. The calculation of the concentration C(x,t).

The hydraulic coefficients Q and U are calculated on the basis of *actual hydrological input data*: observed values of either the water level or the discharge at selected hydrological stations at the time of the accident. The DBAM uses tabulated relations between the water level and the discharge (“rating curves”) to calculate the actual discharge. In a similar way, tabulated relations between the discharge/water level and the velocity are used to calculate the actual velocity.

Strictly speaking, the hydraulic coefficients Q and U are a function of space *only*. By evaluating them at the time of the passage of the cloud for every individual river stretch, they are effectively made time dependent.

The concentrations are computed on the basis of *actual spill input data*: the location of the spill and the amount of material spilled.

The output of the DBAM is presented by animations, tables and graphs, showing the temporal and spatial variation of the pollutant concentration and the variation along the river of the travel time of the cloud and the peak concentration in the cloud.

The input of data as well as the presentation of the results is supported by a modern Windows-based Graphical User Interface. (GUI).

2.4 The accuracy of the DBAM

References: H. Hartong ea. (2000).

In order to explain the notion "accuracy" for the case of the Danube Basin Alarm Model, it is necessary to explain some backgrounds. We will describe below which are the essential steps in the calculation method of the DBAM, and which are the potential inaccuracies arising from each step. Table 2-1 summarises this description .

Phase 1 of the calculation procedure is the collection of the necessary hydrology input data (water levels and/or river discharges). In order to achieve optimal accuracy it is necessary to have accurate hydrology and meteorology forecasts for the full duration of the pollution event. For reference, this period lasted about 4 weeks in case of the Baia Mare spill. It is clear that it is not realistic to assume accurate hydrology and meteorology forecasts over such a long period. The inaccuracy arising from this step affects only the operational use of the DBAM, when it is used in a "forecasting mode". In an analysis in "hind casting mode" with historical hydrology data, there is no inaccuracy as a result of phase 1. This fact offers a possibility to isolate this source of inaccuracies from the remaining sources.

Phase 2 of the calculation procedure is the computation of discharges from water levels, or vice versa, by using the built-in rating curves of DBAM. It is well-known that the concept of rating curves has its limitations and that rating curves are not constant over time. Therefore, the use of rating curves always adds a certain degree of inaccuracy to the result. The latest version of the DBAM allows the user to avoid this inaccuracy by supplying both the water level and the discharge (if these data are available). Again, this fact offers a possibility to isolate this source of inaccuracies from the remaining sources.

Phase 3 of the calculation concerns the computation of the stream flow velocity from the built-in tables. This step presents an additional source of inaccuracy.

Finally, phase 4 of the calculation concerns the actual computation of the propagation of the cloud of pollutants (travel time and concentrations). The fact that the DBAM has not yet been calibrated is a possible source of inaccuracies during this last phase of the computation. It is not immediately possible to isolate this inaccuracy from the part introduced in phase 3.

A final word needs to be said about the inaccuracy stemming from the assumptions underlying the concepts of the DBAM. First, there is the fact that the DBAM uses a constant hydrology per river segment ("quasi-steady"). This aspect is more relevant in hind casting mode, with full hydrology records available, than it is in forecasting mode, when the hydrology forecasts are absent or inaccurate anyway. Nevertheless, the current version of the DBAM allows for the input of a fully time dependent set of hydrology data, so that the inaccuracy on this point can be minimised. A second conceptual problem may be the assumption of 1-dimensionality, which means that no variations in the river velocity or the pollutant concentration over the cross-section are taken into account. This problem is always present, and should be expected to influence the results close to the spill position or close to confluence points.

Table 2-1: An overview of the sources of inaccuracy for the operational use of the DBAM.

Phase in the calculation procedure	Potential inaccuracies
1) Collection of hydrology input data during the event	Inaccuracy or even unavailability of long term meteorological forecasts and hydrology forecasts
2) Computation of discharges from water levels, or vice versa, by using rating curves	Inaccuracy of the rating curves in DBAM
3) Computation of river stream flow velocity, by using built-in tables and the actual water level or river discharge	Inaccuracy of the velocity tables in DBAM
4) Computation of the propagation of the cloud of pollutants (travel time, concentration level)	Inaccuracy of the calibrated model coefficients β (affecting travel time and concentration) and α (affecting only concentrations)
Overall concept of DBAM	Inaccuracy of the underlying assumptions, in particular: • 1-dimensional modelling approach (no variations over the cross-section); • quasi steady hydrology

3 Review of existing information

3.1 The Rhine Alarm Model

References: IKSR/KHR Expertengruppe (1993).

3.1.1 The tracer experiments

The Rhine Alarm Model (RAM) performs a similar role as the DBAM in the Rhine Alarm System. Furthermore, the RAM has the same mathematical foundation as the DBAM. Therefore, the information with respect to the calibration of the RAM is directly relevant for the calibration of the DBAM.

The calibration of the RAM was based on 8 large scale tracer experiments with fluorescent tracers between 1988 and 1991. The organisers claim that tracer experiments on a similar scale had thus far not been reported. Figure 3-1 provides an overview.

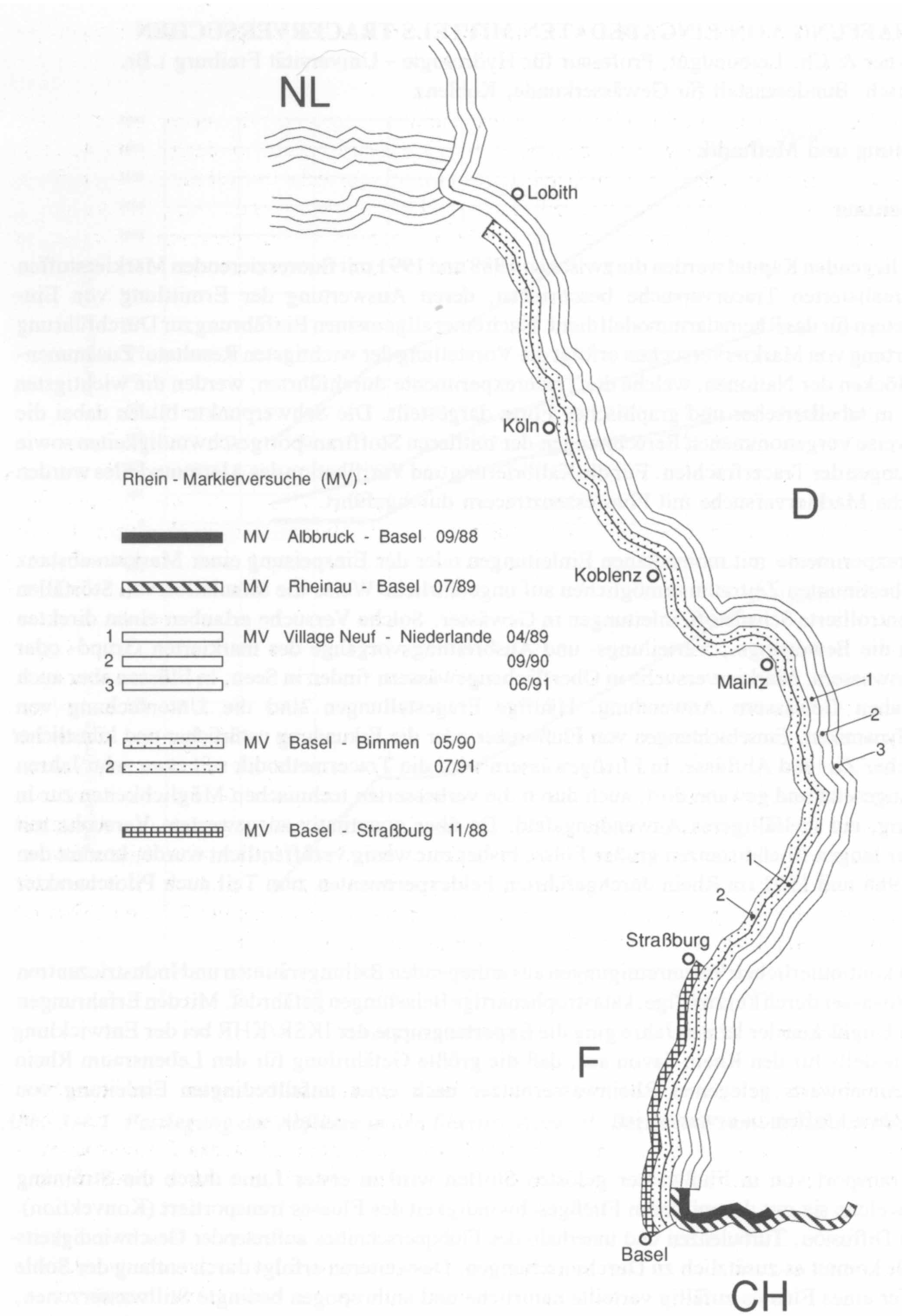

Figure 3-1: Overview of tracer experiments carried out in the Rhine Basin.

The tracer experiments were as much as possible planned to cover a range of discharge conditions. High flow conditions were to be avoided: they occur infrequently, which makes them less relevant, while the river transport characteristics may deviate strongly from those under regular conditions.

The tracer experiments focused on dissolved substances, since these were considered to present the largest threat to the riverine ecosystem. They also focused on the longitudinal transport and spreading of the tracer. Incomplete vertical and lateral mixing over the conveying part of the cross section was not a subject of study.

Three different tracer types were considered: salt, radio nuclides and fluorescent tracers. Salt was rejected because the background levels and the analysis sensitivity would require unrealistically high amounts inputs. Radio nuclides were rejected because of the legal restrictions for their use. Consequently fluorescent tracers were chosen.

Fluorescent tracers are suitable because they can be detected in very small concentrations. Three different substances with different stability were used: Uranine (half-life time 11 h), Acid Red or Rhodamine WT (half-life time 1300 h = 54.2 d) and Rhodamine B (half-life time 780 h = 32.5 d). For the large-scale experiments only the latter two were used.

The tracer releases were intended to be momentaneous releases. The real duration of the discharge was 2 to 6 minutes, except for one release of Rhodamine WT where the duration was 70 minutes due to the formation of a deposit in one of the barrels.

The amounts of tracer released, and the local discharge at the point of release are summarised below.

Experiment	**Tracer used**	**Discharge (m^3/s)**	**Tracer mass (kg)**
MV 09/88	Uranine	712 (Rheinfelden)	235
MV 07/89	Uranine	490 (Rheinau)	200
MV 04/89	Rhodamine WT	1170 (Rheinfelden)	100
MV 09/90	Rhodamine WT	663 (Rheinfelden)	100
MV 06/91	Rhodamine WT	1820 (Rheinfelden)	100
MV 11/88	Rhodamine WT	550 (Rheinfelden)	74.5
MV 05/90	Rhodamine B	1008 (Rheinfelden)	80
MV 07/91	Rhodamine B	1722 (Rheinfelden)	80

Most of the concentration measurements were done with automatic samplers. The samples were stored in brown coloured bottles (to avoid photolysis). Analyses took place in the laboratory, usually with spectral fluorimeters (UV-spectrometry) following the "Synchronscan" method. This is a cheap method. The detection limits of this method are 2 ng/l for Uranine and 6 ng/l for Rhodamine WT. Occasional checks were done with the more accurate but also more time-consuming and expensive HPLC method. The results of these checks matched well.

Simultaneously, in-situ measurements were carried out from ships in some cases. These did not provide information to directly support the model calibration, but they did provide useful background information for data interpretation. Such exercises are particularly useful to get a quick impression of vertical and lateral concentration gradients.

The selection of the (lateral position of the) sampling sites proved critical. Based on the assumption that the tracer mixes rapidly in the vertical and lateral direction, one would expect that this is not a critical factor. Confluences of (large) tributaries without tracers however, may cause substantial lateral concentration differences. Except for such occasions, the sampling was preferably done in the middle of the river, for example using bridges or power stations.

The experiments were organised jointly by the different institutes and agencies involved. Each delivered manpower, sampling and analysis at its own expenses. The results were gathered and reported in close co-operation.

The report concludes:

- the data from the tracer experiments were very fit for purpose;
- it is recommended to simultaneously measure the flow discharge, and especially the variation of it during the passage of the cloud;
- the precise determination of the local flows is even more important for river stretches affected by dams;
- it is recommended to follow-up the large scale tracer experiments, aimed at catching the longitudinal dispersion, with smaller scale experiments to study lateral dispersion phenomena, in the vicinity of the discharge and near confluences;
- Rhodamine B should not be used anymore, due to the associated environmental risks;
- It is recommended to carry out all analyses in one laboratory.

3.1.2 The model calibration

The RAM was calibrated on a subset of the available tracer experiments, and verified on the remaining data.

Target parameters were β (effective dead zone parameter) and α (longitudinal dispersion parameter). The parameter β affects both the travel speed and the concentration levels, while the parameter α only affects the concentration levels.

The calibration consisted of two stages:

- estimation of β and α over reaches between two subsequent observation points by mathematical formulas from the observed transport time (referring to the passage of the peak concentration) and the observed overall dispersion;
- refinement of the estimate by formally minimising the average deviation σ between the observed and the computed concentrations (that is: minimising $\partial\sigma/\partial\beta$ and $\partial\sigma/\partial\alpha$).

The calibration report mentions other sources of inaccuracy than the imperfect calibration of β and α, but no effort is made to quantify them.

The calibration circumvents the estimation of a third parameter δ, expressing the decay of the tracer by re-running the model for every river stretch with the locally recovered tracer mass, with the decay of the tracer set to 0.

At the end the following conclusions are drawn:

- values of the parameter β are in the range of 0 to 0.3;
- values of the parameter α are in the range of 0.002 (for canals), to 0.01 (rivers of moderate slope) and 0.02 (lowland rivers);
- incomplete mixing downstream of the release point and of confluences leads to deviations between the predicted and the observed transport time;
- except for the first 50 to 100 km, the model reproduces the transport times typically within 5%;
- due to the fact that the decay of the tracer has not been included in the calibration and verification process, no estimate could be made as to the accuracy of the predicted concentrations;
- the shape of the clouds of pollutants could very well be represented by the model.

3.1.3 Further research

Additional work has been done on the Rhine Alarm Model, based on available records from accidents and on regular water quality monitoring (Lorenz, 1997 and Vollstedt, 2000).

3.2 The Danube Basin Alarm Model

3.2.1 Set-up and implementation of the AEWS, DBAM pre-study

References: WL | Delft Hydraulics (1994), WL | Delft Hydraulics (1996a), WL | Delft Hydraulics (1996b).

These references present no relevant information in the present context.

3.2.2 Implementation of the DBAM

References: VITUKI Plc, STU, ICIM, NIMH and RIZA (1996).

The first version of the DBAM was completed in 1996. This included the development of the software and the compilation of the underlying river schematisation as well as the rating curves and the river velocity tables.

The calibration of the model was not a part of the implementation. The model parameters were given estimated values, derived from the experience with the RAM. However, a "tracer feasibility study" was carried out and reported. This study consisted of separate contributions from the different Consortium members from The Netherlands, Romania, Hungary and Slovakia.

On several occasions the authors mention the possible use of natural tracers. Concentration differences of certain pollutants between a tributary and the main river can be used to track the lateral dispersion process. Temporal variations of the concentration of certain parameters can be used to track longitudinal dispersion. The latter occurs in the Rhine river due to large non-constant brine discharges. The Hungarian section of the report mentions the possibility to in-situ measure the conductivity of the water with sounding techniques, which is cheap, fast and reliable.

A distinction is made between large scale experiments to calibrate the longitudinal spreading and small scale experiments to investigate specific areas (Bös-Gabcikovo, islands near Budapest, Iron Gates, Delta, etc.) and to investigate lateral mixing. For the former a suggestion is done to cut the Danube in two: upstream and downstream of the Iron Gates reservoir.

Suggestions are made for the locations for future tracer experiments, but it is not always clear what are the underlying objectives and conditions.

From the report it shows that substantial experience with small scale tracer experiments exists in Hungary and, to a lesser extent, in Slovakia. This shows among other things from the detailed recommendations on the organisational aspects, such as the mobilisation steps listed in the Hungarian section.

Some creative ideas of the Romanian author are worth mentioning. A suggestion is made to use floats as an indicator of transport time (like it is routinely done in marine research). Furthermore, the idea is formulated to use remote sensing images to analyse lateral mixing phenomena downstream of tributary inflows. It should be investigated if such techniques have been successfully applied elsewhere.

Other aspects mentioned are:

- the need for a permit to apply fluorescent tracers;
- the recommendation to carry out sampling at locations inside the regular water quality monitoring networks;
- to treat singularities like locks, dams and barrages with special attention;
- practical experience with the tracer sodium fluorescine (reported detection limit 0.02 mg/l).

3.2.3 Methods for calibration experiments ("project AE2")

References: Phare Environmental Consortium (1998).

This reference presents an extensive volume of work carried out in preparation to the calibration of the DBAM. It was mainly based on the sources of information discussed above. Although a lot of valuable information was presented by the author, this reference does not present a clear and concise synthesis of the collected information. At present we have used the Executive Summary to identify aspects of interests and scanned the remaining text for the necessary details.

The report presents the use of Br-82 (radioactive) and Rhodamine WT (fluorescent) tracers as *proven technology*. The use of these tracers is supposed to be inhibited or complicated by environmental legislation (not in a concrete way however, by stating that the use of tracer X violates regulation Y of country Z). Therefore, alternative techniques are identified based on the injection of "natural tracers" (suspended matter, biological material), remote sensing images and existing concentration gradients (WWTP effluents). These techniques are however classified as "experimental", and their application should be preceded by a pilot project. No clear choice is made.

The report proposes a seven step calibration procedure which is claimed to be realistic and feasible. This procedure deviates from the one used in the Rhine Basin in the sense that it makes use of supportive "HD-AD" models. This is motivated by cost considerations (minimizing expensive field work) and time considerations (implementation time). The use of an alternative procedure is not supported by an objective comparison in terms of implementation time and implementation costs between the *proven* Rhine Basin approach and the suggested alternative approach. In contradiction to the initial conclusion, the use of the proposed new approach necessitates a pilot project to investigate the feasibility (!).

Contrary to the Rhine approach, a focus on in-situ measurements is proposed. This is probably based on costs considerations. Again, no objective comparison is presented.

The role of the proposed supportive "HD-AD" models is twofold: (1) to plan the experiments and (2) to avoid multiple experiments under different flow conditions.

The cost estimates presented are dominated by investment costs for the tracer experiment equipment, which is presumably bought for the sole purpose of calibrating the DBAM.

3.2.4 Strengthening the Danube AEWS

References: H. Hartong ea. (2000).

This project did not pay a lot of attention to the calibration aspects of the DBAM. Some preparatory works were carried out:

- the verification and (where necessary) correction of the rating curves and the velocity tables of the DBAM (constituting two sources of model inaccuracy, see par. 2.1);
- an inventory of existing 1D "HD-AD" models (following the proposed role of such models in the calibration methodology proposed in the project AE2, Phare Environmental Consortium, 1998).

In the conclusions attention was requested for the maintenance of the rating curves and the velocity tables of the DBAM as well as the continuous evaluation of the operational availability of the necessary hydrology input data. Both are intended to minimise the related sources of model inaccuracy.

Based on data collected during the Baia Mare spill event, some test computations have been carried out with version 2.00 of the Danube Basin Alarm Model. The observed river stretches are the Somes-Tisa on Hungarian territory and the Danube on its course along the Romanian border. From these calculations the following conclusions were drawn:

- The accuracy of the predicted travel times is good over longer distances: the cumulative error is 6% for the Somes-Tisa stretch (about 600 km) and 5% for the Danube stretch (about 1000 km).
- Looking at smaller river stretches of about 100 km, larger errors occur in the predicted travel times: up to 25% in both the Somes-Tisa and the Danube cases. These errors are not systematic however, over longer distances they tend to compensate.
- The error of the predicted peak concentrations along the Tisa is between 26% and 57%. For the Danube this aspect has not been analysed.

Some additional test computations were carried out based on the Somes-Tisa stretch, in order to get an insight in the potential improvements from the future calibration of the DBAM. From these calculations the following conclusions were drawn:

- It will be possible to improve the predicted travel times drastically, by tuning the space dependent β parameter.
- If certain river stretches turn out to need values of β outside of the expected range without any physical reason for it, it is necessary to check and if necessary improve the rating curves and velocity tables in the DBAM.
- It will be possible to improve the predicted peak concentrations to a large extent, by tuning the space dependent α parameter.
- Nevertheless, one should not expect a perfect fit with respect to the predicted concentrations, due to the conceptual limitations of the DBAM.

With respect to the calibration the following recommendations were made:

- to focus on travel times first;
- to use as much as possible historical data from recorded spills;
- to try to find data for different spills under different hydrological conditions;
- not to forget the inaccuracies stemming from the use of rating curves and velocity tables;
- to use good quality authentic field data from the responsible authorities to correct the rating curves and velocity tables.

In addition to this, carefully planned tracer experiments can be used to fill in the gaps.

A question mark was placed at the use of 1D HD-AD models, as suggested by the AE2 project (Phare Environmental Consortium, 1998). Particular concerns are:

- a HD-AD model does not have any predictive power with regard to the main calibration parameters of the DBAM (α and β);
- while a numerical HD-AD model is better in representing the full dynamics of the river flow, it has a major drawback as compared to the analytical DBAM: it suffers from a fundamental inaccuracy called "numerical dispersion" which is bound to seriously complicate the calibration of dispersion-like processes;
- both the DBAM and any hydrodynamic model are only reliable if the data behind them are reliable: if a hydrodynamic model is available based on much better data than the DBAM, these data can be used immediately to improve DBAM, without the intermediate step of setting up and running the hydrodynamic model.

3.3 Experience from the Elbe River

In the Elbe catchment the *Internationalen Alarmmodell Elbe (ALAMO)* is used to calculate the transport and dilution of a cloud of pollutants in the river. To support the calibration and validation of this model, several tracer experiments have been carried out (ao. in July and December 1997). The text below provides relevant aspects related to the planning and execution of the July 1997 experiment. Furthermore, some technical details about the model.

3.3.1 The July 1997 tracer experiments in the Elbe River

Reference: H. Hanisch ea. (1997).

The tracer experiment was carried out along the German part of the Elbe, between Schmilka, at the Czech-German border and Geesthacht, upstream of Hamburg. The distance is 580 km, the overall travel time 11 days.

The experiment was done with the tracer substance Amidorhodamine G. It was selected for different reasons: (1) no toxicological effects were found during specific tests by the German Institut für Wasser-, Boden- und Lufthygiene, (2) it has suitable physical characteristics (good solubility and stability, not affected by adsorption to particles), and (3) its fluorescence does not depend on the temperature and the pH. The literature provides a limit concentration of 100 µg/l.

The amount of tracer applied was determined as 10 kg per 100 m^3/s of river discharge. The discharge of the tracer was made from a ship traversing the river, to obtain as much as possible initial transversal mixing of the tracer substance. Only in the immediate vicinity of the discharge (7 km downstream) concentrations just above the limit concentration of 100 µg/l were observed. The use of this tracer was fully satisfactory.

The density of stations was significant: 28 stations over 580 km of river stretch (average distance between stations about 20 km).

The experiment was based on sampling and subsequent analysis of the samples. In-situ measurements at distinct locations were used for timing the “sampling time window” at the stations immediately downstream. The river discharge turned out to be highly variable during the period preceding and during the tracer experiment. The estimates for the sampling windows made before the experiment were inaccurate: the in-situ measurements were used to adapt these estimates during the course of the experiment.

The operation of the samplers proved to be sensitive to failures and servicing. The samplers from the upstream stations were transported to a downstream station after the passage of the cloud. This is a way to optimise the necessary amount of equipment.

The samples were analysed by Spectral Fluorometer (Perkin Elmer) in a central laboratory.

Simultaneous measurements of the river discharge were carried out during the experiment at different stations.

The experiment was organised within a period of 10 weeks, which was in retrospect too short.

3.3.2 The ALAMO model

Reference: Presentation by W. Blohm (Appendix B).

The ALAMO model is in many respects comparable to the DBAM. The underlying mathematical concepts are identical (paragraph 2.2). Regarding the implementation some differences exist. These are listed below.

- The ALAMO solves the governing mathematical equations by a numerical method.
- The ALAMO does not accept an observed time series for the concentration C(t) as input (in stead of a spill location and a spill mass).
- The ALAMO automatically retrieves its hydrology input data.
- The ALAMO includes a list of substances and relevant alarm levels.
- The ALAMO produces a spill report in ASCI format.
- The error in the predicted travel time was 4% before calibration and decreased to 2% after calibration. This error is much smaller than that in the Rhine Alarm Model, maybe because of the relative simplicity of the river system (few tributaries, no weirs).

3.4 Advances in transport modelling

Recent publications indicate that the results from tracer experiments can be treated in such a way that they can separately assess the accuracy of the velocity tables and the values of the model parameters α and β (van Mazijk, pers.comm.). In the terminology of paragraph 2.4, this means that the inaccuracy corresponding to Phase 3 of the calculation can be separated from the inaccuracy stemming from Phase 4. This will be further elaborated in the project preparatory documents.

3.5 Specific conditions in the Danube Basin

Although the cases of the rivers Rhine and Elbe and several French rivers present successful examples of the use of tracer experiments to calibrate models like the DBAM, the specific characteristics of the Danube Basin should be taken into consideration:

- natural environment: geometry (2800 km length, at least 2 major international tributaries) and hydrology (an average of 6000 m^3/s);
- social environment: 13 countries, different languages, large differences in GDP;
- water management infrastructure: inhomogeneous environmental legislation, possibly varying quality of institutions and staff to organise and support tracer experiments and to analyse samples.

4 Synthesis: Calibration Options

4.1 Integrated "*DBAM usability enhancement plan*"

The objectives for the current project demand a solid base for the DBAM calibration and future use. This requires that sufficient conditions are created to optimise the accuracy of the DBAM. Furthermore, this requires that the DBAM is properly maintained.

4.1.1 Accuracy of the DBAM

The accuracy of the DBAM depends on more than just an accurate calibration of the model parameters α and β. Table 4-1 lists some conditions to ensure optimal model performance (see also paragraph 2.4).

Table 4-1: An overview of the conditions for optimal accuracy of the DBAM.

Phase in the calculation procedure	**Conditions for accuracy**
1) Collection of hydrology input data during the event	Actual hydrology data for the stations included in the DBAM can be obtained under conditions of use.
2) Computation of discharges from water levels, or vice versa, by using rating curves	Rating curves in DBAM are accurate.
3) Computation of river stream flow velocity, by using built-in tables and the actual water level or river discharge	Velocity tables in DBAM are accurate.
4) Computation of the propagation of the cloud of pollutants (travel time, concentration level)	DBAM is properly calibrated.
Overall concept of DBAM	Underlying assumptions affecting the model accuracy are well understood, in particular: • 1-dimensional modelling approach (no variations over the cross-section); • quasi steady hydrology

As a part of the present project, the Consultant also intends to make recommendations related to aspects 1), 2) and 3) from Table 4-1. This implies that somehow arrangements must be made to periodically verify the operational accessibility of the necessary hydrological input data as well as to periodically check the DBAM rating curves and velocity tables. The Workshop participants are requested to provide the necessary input to draft these recommendations.

4.1.2 Maintenance of the DBAM

To ensure the sustainable and efficient use of the DBAM, maintenance provisions should be in place, which could for example consist of:

- Archiving of software, data and documentation;
- Distribution of software, data and documentation;
- Upgrades of software and documentation for new platforms (Windows 2000, Windows XP).
- Functional upgrades of software.
- Regular upgrades of hydrology stations, rating curves and velocity tables (see 4.1.1).

As a part of the present project, the Consultant intends to make recommendations in this respect. The Workshop participants are requested to provide the necessary input to draft these recommendations.

4.2 Scope and objectives of the DBAM calibration exercises

Since the Rhine Alarm Model (RAM) is based on identical principles as the DBAM, the calibration of the RAM presents a very relevant example. For the calibration of the RAM, a hierarchic set of objectives was defined:

- In view of the trans-boundary use of the model, to first focus on the main river and the large international tributaries, in order to properly evaluate the longitudinal dispersion.
- To follow up with detail studies, directed towards river anomalies (locks, weirs, dams, reservoirs) and lateral dispersion phenomena (vicinity of the discharge, confluences).

It should be confirmed by the Workshop participants that this approach is also suitable for the Danube. As a next step, this should be made more concrete: which international tributaries will be part of the calibration exercises? In view of the possible budget and time restrictions, different classes of priority could be distinguished.

4.3 Existing data or additional tracer experiments?

Carrying out tracer experiments on the scale of the Danube River is a costly exercise. A very relevant question is to what extent existing data can be used to evaluate and calibrate the longitudinal dispersion of pollutants in the Danube and its main tributaries.

Two types of existing data can be used:

- Records from accidental spills.
- Continuous records of the water quality, related to parameters showing distinct temporal gradients (see for an example Figure 4-1).

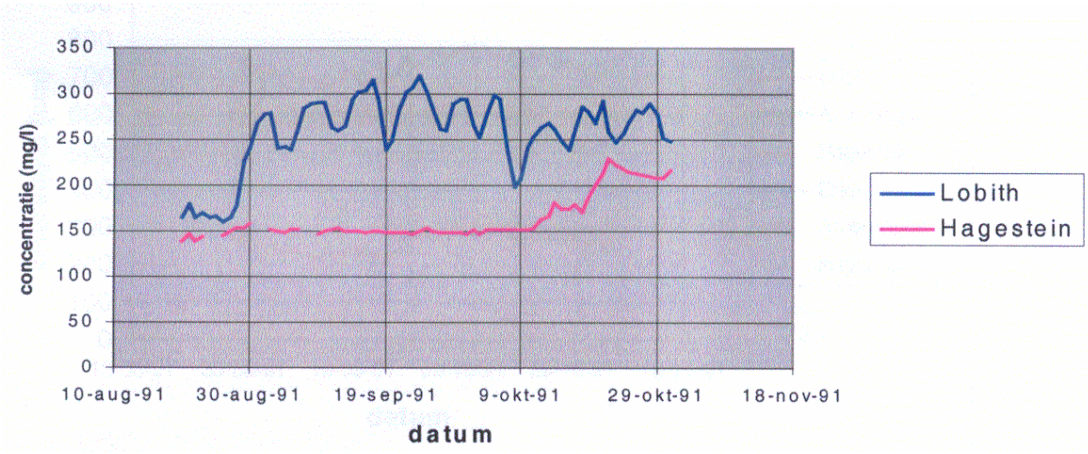

Figure 4-1: Example of continuous concentration records showing strong temporal gradients. The chlorides concentration at Lobith (Rhine river, border Germany-The Netherlands) shows a strong increase near the end of August 1991. This increase arrives at Hagestein (Lower Rhine river, about 80 km downstream of Lobith with several weirs in between) around half of October. This information has been used to calibrate and validate the Rhine Alarm Model on this particular stretch.

The following information should be available (for both types of data):

- The concentration as a function of time at 2 or more locations.
- The necessary hydrology data as a function of time at *all DBAM hydrology stations along the river stretch of interest*. The frequency should be daily at least.

The Consultant needs to be able to judge to what extent existing data could be used for calibration purposes. The Workshop participants are requested to provide the necessary input. They will have to do so in the period before the actual workshop, or in the period immediately following the workshop.

4.4 Set-up of additional tracer experiments

4.4.1 Selection of tracer substance

Different (types of) tracers can be considered in regard to the set-up of additional experiments.

Table 4-2 provides some options, with their respective advantages and disadvantages.

Table 4-2: Overview of different types of tracer substances.

Type of tracer	**Advantage(s)**	**Disadvantage(s)**
Salt	Low ecological impact Low price	Extremely high dosage required to significantly exceed background level (> 10 mg/l).
Radio nuclides	High sensitivity (detection possible at very low concentrations) Proven technology (?) Possibility of in-situ analysis (?)	Legal restrictions (?)
Fluorescent tracers	Proven technology Relatively high sensitivity (detection possible at low concentrations) Possibility of in-situ analysis	Possible adverse ecological impacts. Legal restrictions (?)
Other natural tracers (suspended matter, biological material)	Low or no ecological impact	Experimental (feasibility study required)

The Workshop participants are requested to provide the necessary input for selecting the most appropriate option. Especially relevant are the relevant legal restrictions which apply in the different Danube countries.

4.4.2 Sampling and analysis

The tracer experiments in the Elbe and the Rhine rely on the collection of samples and a subsequent analysis in the laboratory. Two contradicting requirements/recommendations exist with respect to the sampling and analysis:

- it is necessary to analyse the samples rapidly, in view of the ongoing decay of the tracer material;
- It is recommended to carry out all analyses in one laboratory.

Considering the large size of the Danube and its major trans-boundary tributaries, this may lead to two alternative approaches:

"Central" approach	**"Decentral" approach**
Collect samples from the whole experiment and transport to one central laboratory for analysis	Collect samples from limited river stretches and transport to several laboratories for analysis (e.g. one per country)
Transport times tend to become higher (crossing borders critical)	Transport times will be lower
Comparability of results optimal	Comparability sub-optimal, can be mitigated by analysing "border samples" in two laboratories

The Workshop participants are requested to provide the necessary input for selecting the most appropriate option.

4.4.3 Selection of stations and observation windows

From the existing experience it follows that two aspects are very important:

- The stations should not be too close to river anomalies or large tributary inflows.
- For reasons of efficiency the "observation window" should be carefully selected. The DBAM in its present form could be used for that purpose, allowing for a 10-20% error in the propagation time of the cloud. In-situ observations could be used to check and possibly correct the observation windows during the experiments (as in the July 1997 Elbe experiment).

Alternative approaches can be distinguished with respect to the station density:

High density of stations	**Low density of stations**
Typical distance between subsequent stations << 100 km	Typical distance between subsequent stations > 100 km
Spatial variation of calibration parameters well resolved	Spatial variation of calibration parameters not so well resolved
Smaller number of tracer experiments for the same budget, so less opportunities to check DBAM at different flow regimes	Higher number of tracer experiments for the same budget, so more opportunities to check DBAM at different flow regimes
Smaller number of tracer experiments for the same budget, so less opportunities to check DBAM along different tributaries	Higher number of tracer experiments for the same budget, so more opportunities to check DBAM along different tributaries

From prior experience we know that the spatial variability of the calibration parameters can well be derived from general river characteristics. It is probably more effective to check the quality of the built-in rating curves and velocity tables at different flow regimes or along different tributaries. This is an argument in favour of the low density of stations approach.

The Workshop participants are requested to provide the necessary additional input for selecting the most appropriate option.

4.4.4 Collection of hydrology data

A very clear recommendation from earlier exercises is the complete collection of the relevant hydrology data. The water levels and/or river discharges data should be obtained as a function of time at all DBAM hydrology stations along the river stretch of interest. The frequency should be daily at least. It should be emphasised that without this information the execution of tracer experiments is useless.

The Workshop participants are invited to provide the necessary recommendations to guarantee the availability of the necessary hydrology data.

5 Preparation of the Workshop

The main questions raised in the Synthesis above have been addressed during a dedicated Workshop. This workshop has been attended by the APC/EG members, which represent the beneficiaries of present project: the 13 member countries of the ICPDR (see Appendix C).

The short term objectives of this Workshop were dual: to (1) ensure sufficient understanding of the DBAM and its calibration procedure with the APC/EG members, and (2) to obtain input from the participants to complete the preparation of the calibration of the DBAM.

An additional medium term objective is to ascertain the support from the APC/EG members for the calibration and future use of the DBAM.

The workshop consisted of different parts:

- Explanations: (a) DBAM principles, and (b) factors determining the accuracy of the DBAM;
- Elaborations: (a) DBAM usability enhancement, (b) scope and objectives, (c) existing data vs. additional experiments, and (d) set-up of additional experiments;
- Evaluations: formulation of conclusions and recommendations of the remainder of the project.

Part 1 was presented by the Consultant, while the parts 2 and 3 have been elaborated by the Workshop participants, facilitated by the Consultant and the UNDP/GEF project staff.

Appendix A provides the Draft Agenda of the Workshop, which was accepted without modifications and followed without major changes.

Separately the Consultant has prepared the required *Templates for Planning, Organising, Documentation and Evaluation of Workshops* (Nauheimer, 2002).

Appendix B provides the relevant presentations used during the Workshop, prepared by the Consultant and by Dipl.-Ing. Werner Blohm (Hamburg, Institut für Hygiene und Umwelt), who was invited to present some aspects of the use of the Elbe alarm model ALAMO.

6 Recommendations for follow-up (Workshop Report)

The present chapter presents the conclusions and recommendations which were formulated during the Workshop by the participants. The chapter follows the structure presented in the Calibration Options Chapter 4. First, the availability and the utilisation of the DBAM will be discussed. This discussion will provide the necessary conditions (including the necessary maintenance arrangements) for any calibration exercise to be successful. Next, the specific aspects of a future calibration action will be outlined.

Since the Workshop followed exactly the same agenda as the lay-out of the present chapter, this chapter can be read as the Workshop Report.

Although it was not a primary subject of the Workshop, some extensions of the present DBAM functionality were suggested. For the sake of completeness, they are listed in Appendix F. It should be noted that these suggestions are not necessary preconditions for the future use of the DBAM.

6.1 Availability and utilisation of the DBAM

6.1.1 Current status

Preceding the workshop, an inventory was made by the APC/EG member György Pinter of the current status with respect to the availability and utilisation of the DBAM. The inventory is included as Appendix D to this report.

The inventory reveals that few Principal International Alert Centres (PIACs) are actually using the DBAM. The reasons for this are:

- Unavailability of the software;
- installation problems;
- running problems.

Both the installation and running problems are caused by the fact that the latest DBAM version (2.00.02, October 2000) is not suited for use on modern Windows-based platforms like Windows 2000 and Windows XP.

There was agreement between the participants that the first problem should be solved by distribution of the latest version of the software through Danubis. The latter two problems should be tackled by making adequate maintenance provisions (Appendix E contains draft ToR for such provisions).

6.1.2 Target accuracy of the DBAM

During the Workshop, the present accuracy of the (uncalibrated) DBAM was discussed, as well as the factors which determine its accuracy (see paragraph 2.4). A relevant question is how accurate the DBAM should be, in view of its role in the AEWS.

The Workshop participants agreed that the target accuracy in the prediction of the travel time of a cloud of pollutants should be a 5% (relative error). This value is equal to the reported accuracy of the Rhine Alarm Model after calibration. The Elbe model is reported to be more accurate, most probably due to the fact that the Elbe is a simpler river to model: it is a natural river without bifurcations and parallel stretches.

No concrete value for the accuracy of the predicted peak concentration was discussed. The Rhine Alarm Model was not calibrated on this particular aspect. In stead, the calibration targeted at prediction the right shape of the cloud of pollutants. Of course, this would indirectly guarantee the correct prediction of the concentrations if the spill mass and the decay rate of the spilt substance are known. Since it is in practice very hard to obtain reliable estimates of these numbers, it is hard to set targets for the accuracy of the predicted concentrations. Our expert opinion is that an error by a factor of 2 is probably the best achievable accuracy under operational conditions.

6.1.3 Hydrology data

The availability of hydrology data under operational conditions is an important factor affecting the accuracy of the DBAM. During the Workshop different questions were discussed:

- What is current practice in collecting hydrology data?
- Is there any transfer of this information between the countries?

The PIACs mostly use only the hydrology data from their own country. Exchange of data is arranged on an ad-hoc basis through personal contacts and/or through the AEWS system. The representative of Slovenia reported this as being unsatisfactory: the travel time of the river demands a faster means of data exchange.

- Is there an organisation collecting these data on a Danube wide scale?
- To what extent could this information be collected from the Internet?

To the knowledge of the Workshop participants, there is no organisation collecting the data at the Danube scale. The Internet only provides part of the necessary data.

- Is it possible to use predefined hydrology conditions files for operational use of the DBAM? (high-low-medium flow situation)

The participants to the Workshop judged that this was definitely a valuable approach. This allows the PIAC staff to carry out an approximate assessment plus sensitivity analysis without any data at all.

The participants agreed that the ultimate solution will be that all PIACs can access the necessary data via the internet directly. Where such data are not public, the PIACs should obtain access rights for AEWS purposes only (all PIACs should be issued passwords to the websites of the Hydrometeorological Institutes in the basin).

This should be realised in two steps:

- At the technical level it should be formulated exactly what information is needed from what source. Any technical optimisations should be carried out at this stage.
- At the political level, a request for these data to be made available should be submitted to the Heads of Delegation.

It should be noted that an effort as specified under (1) has been carried out in 2000 (Hartong, 2000).

6.1.4 Rating curves and velocity tables

The accuracy of the DBAM built-in tables is yet another important factor affecting the accuracy of the DBAM. Therefore, the maintenance of these tables was jointly recognised as a precondition for the sustainable use of the DBAM.

The national Hydrometeorological Services in the Danube countries are in most cases the owners of the data in the DBAM tables. Therefore, these institutions should also maintain them. Table 6-1 provides a brief overview. For details, we refer to (Vituki, 1996).

Table 6-1: Overview of institutes owning the data supporting the DBAM built-in tables.

Country	**Institute**
Hungary	Vituki
Croatia	Croatian Waters/ State Hydrometeorological Institute
Serbia and Montenegro	Hydrometeorological Institute
Bulgaria	Institute of Hydrology and Meteorology
Romania	Hydrology and Water Management Institute (Romanian Waters)
Slovakia	Slovak Hydrometeorological Institute
Czech Republic	Czech Hydrometeorological Institute
Slovenia	Environmental Agency of Slovenia

It was agreed that the APC/EG members will have the responsibility to liaise with these services and obtain updated information on a regular basis. The “central level” (ICPDR/DRP) will be responsible to archive the data and provide upgrades of the DBAM based on this new data.

The built-in tables from the existing version should be made available on Danubis.

6.2 Future calibration of the DBAM, supported by tracer experiments

6.2.1 Current status

The pre-calibration accuracy of the DBAM was discussed on the basis of the evaluation of the Baia Mare incident (Hartong, 2000). The accuracy of the predicted travel time of the cloud over longer distances is quite satisfactory: a relative error of 5% (500-1000 km). Over shorter distances however, the errors are significantly larger (up to 25%). This is clearly insufficient.

The participants rightly point at the validity of the underlying model concepts and the reliability of the data input data as inherent factors limiting the accuracy of the accuracy of the DBAM under operational conditions. The future calibration efforts will have to be organised in such a way that these factors are eliminated as much as possible. This will be elaborated below.

6.2.2 Scope and objectives (including priorities)

The Workshop participants discussed the scope and objectives for the future DBAM calibration. Below, the main conclusions are formulated.

Apparently, the DBAM and therefore also the future calibration focuses on transboundary rivers. Given the scale of the basin, it is considered infeasible to carry out a basin-wide calibration exercise initiated from the central level. Such an approach is infeasible both from a technical and from a political point of view.

In stead, it is advised to carry out the future calibration on the basis of local initiatives by a limited number of Danube states (“bottom-up” approach).

The prioritisation of the areas for calibration should be based on different considerations. The first aspect is the presence of hot spots (sites of high potential risk for accidental spills). An inventory of such sites is already available. A second aspect is the presence of areas with sensitive water uses. An inventory of such areas is expected to be available at the end of 2004. On the basis of the above considerations, the Workshop participants agreed on a number of concrete proposals, including a prioritisation. Table 6-2 gives an overview.

Table 6-2: Overview of priority areas for model calibration.

Area	Priority
Sava basin (co-operation with Sava initiative)	1
Upper Tisa (Spill in Uh, followed till inflow of Zagyva)	1
Middle Danube (water intake Budapest)	2
Lower Danube (joint Romanian-Bulgarian border stretch)	2
Drava	2
Prut	3

6.2.3 Existing data or new experiments?

The Workshop participants agreed that available existing data should be used in the future calibration of the DBAM. The following information should be available (for both types of data):

- The concentration as a function of time at 2 or more locations.
- The necessary hydrology data as a function of time at all DBAM hydrology stations along the river stretch of interest. The frequency should be daily at least.

An inventory of such data based on information provided by the participants is given in Appendix G..

6.2.4 Selection of tracers

Regarding the selection of tracers for possible future experiments in the Danube basin, two guiding principles were agreed upon during the Workshop:

- Permitting is a major issue. The Phare Environmental Consortium (1998) has made an inventory of relevant legislation. Appendix H provides an actualised overview.[1]
- Only proven technology should be used.

The use of salt may be an interesting option for smaller rivers. The Hungarian representative in the APC/EG indicated that on the Sajo river a planned intermittent large discharge of chlorides can be used as a tracer experiment.

Appendix I provides guidelines on the tracer mass to be applied for a river with given physical and hydrological characteristics, in relation to the detection limit of the tracer substance in question and the maximum allowable concentration (MAC). These guidelines can be used to minimise permitting problems.

6.2.5 Sampling and analysis

The participants agreed that the selection of a central or decentral sampling and analysis strategy is to be made separately for every individual experiment. In the case of a decentral approach, a preparatory intercalibration programme between candidate institutes should be included in the project plan.

The APC/EG experts indicated that the comparability of the results from different laboratories should not present a major problem in the case of fluorescent tracers, since the analysis is simple.

6.2.6 Density of stations

The participants agreed that the density of stations should be decided separately for every individual experiment. Small fast flowing rivers need a higher density than larger rivers. Local knowledge should a decisive factor in this respect.

[1] *Recently, BASF has conducted tracer experiments in theRhine with Na-24-Acetate, a radio nuclide. Apparently, there is room for such experiments in the German legislation.*

Decisions about the position of sampling in the cross section should be made consciously: either cross sections where incomplete mixing is expected should be avoided (as during the Rhine experiments), or samples should be taken at different positions, as in the Transnational Monitoring Network TNMN (Left-Middle-Right).

It should be noted that during the Elbe tracer experiment, initial lateral mixing was obtained by releasing the tracer from a ship traversing the river.

6.2.7 Frequency of sampling

The participants agreed that the frequency of sampling should be decided separately for every individual experiment. Small fast flowing rivers need a higher frequency than larger rivers. Based on the mathematics of the DBAM a rule of thumb can be established (Appendix J).

6.2.8 Hydrology data

The Workshop participants agreed that the complete collection of the relevant hydrology data is a necessary condition for every tracer experiment. The water levels and/or river discharges data should be obtained as a function of time at all DBAM hydrology stations along the river stretch of interest. The frequency should be daily at least.

6.2.9 Organisation and financing

Regarding the organisation of future tracer experiments, the participants agreed that a decentral approach is the most appropriate. The necessary activities should as much as possible be carried out and financed by the participating countries. The central level would have a purely supportive role, which consists of:

- Initiating activities.
- Organisational support.
- Methodological support.

With respect to the last aspect, Appendix K provides the outline of a calibration manual.

7 Epilogue

The present report describes the conditions and activities which are supposed to provide a technically sound basis for the DBAM calibration (during Phase 2 of the Danube Regional Project) and for the future use of the model.

This was achieved by a stepwise approach:

- The formulation of options and alternatives, on the basis of relevant literature and existing practice from the Danube basin.
- An in-depth discussion with the stakeholders during a Workshop.
- The formulation of conclusions and recommendations.

By following this approach, some necessary preconditions were created to ascertain the support from the APC/EG members for the calibration and future use of the DBAM. In particular the Workshop served to ensure sufficient understanding of the DBAM and its calibration procedure from the side of the APC/EG members, and to make sure that the knowledge and views from the APC/EG members was optimally used for the formulation of conclusions and recommendations.

Concrete actions need to be taken in order to ascertain the future use of the model. In the first place, the distribution of the software should be better organised and a provision for maintenance and support should be created. In the second place, the accuracy of the model should be improved. This should be achieved in two steps:

1. Data collection step:
   the gathering of existing data and the creation of new data by means of tracer experiments.
2. The calibration of the DBAM, based on the collected data.

Chapter 6 provides the necessary guidelines in relation to the distribution and maintenance and support of the DBAM. Furthermore, Chapter 6 provides guidelines on the collection of data, including a concrete proposal of "pilot areas" for tracer experiments. Appendix K provides an outline of the Calibration of the DBAM.

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A Draft Workshop Agenda

Date: 9-10 September 2003.

Place: Ljubljana, back-to-back with a regular APC/EG meeting.

9 September 2003.

14.00h Welcome *DRP project staff.*

14.15h Introduction to the project \ Workshop agenda *Jos van Gils*

14.30h Availability and utilisation of the DBAM *APC/EG Representative*

15.00h Discussion

15.30h Break

16.00h Conclusions and recommendation w.r.t. availability and utilisation of the DBAM, implications for the DRP *APC/EG Representative, DRP Staff*

16.30h History and principles of the DBAM *Jos van Gils*

17.00h The Rhine and Elbe examples *Werner Blohm, Jos van Gils*

18.00h End of meeting

10 September 2003.

Discussion on specific aspects related to the calibration and future use of the DBAM.

Every item is introduced by *Jos van Gils*, and subsequently discussed. For every aspect a seperate chairperson and reporter will be chosen by the group. The reporter will summarise the discussion. *Jos van Gils* will draft the Minutes. Coffee breaks will be inserted at an appropriate time. Tentative time schedule:

9.00h Factors affecting the accuracy of the DBAM, role of calibration (illustrated by the Baia Mare case)

9.30h DBAM usability enhancement

9.45h Scope and objectives of the calibration

10.15h Availability of existing data and need for additional experiments

11.15h Selection of tracers (*including possible presentation of IAEA representative*)

12.30h Lunch break

14.00h Sampling and analysis

14.45h Density of stations

15.30h Hydrology data

16.00h Closing remarks

16.30h End of meeting

B Workshop presentations

wL | delft hydraulics

Development and maintenance of the DBAM Danube Regional Project, activity 2.3-4

Consultant: Jos van Gils
Delft Hydraulics

wL | delft hydraulics

Objectives of this project activity

To provide a technically sound basis for
the calibration of the DBAM (during Phase II of the DRP)
and for the future use of the model

wL | delft hydraulics

Activities and products

- Calibration options report
- Preparation of workshop with APC, UNDP-GEF team, ICPDR representatives and invited guest:
  - experiences from other basins (Rhine/Elbe)
  - presentation of options for calibration approach
  - selection of best alternatives
- Elaboration of preparatory documents along the lines laid out during the Workshop:
  - draft project brief and ToR's for Phase II
  - calibration manual
  - recommendations

icpdr iksd

Danube Regional Project UNDP GEF

wL | delft hydraulics

Calibration options report

- Backgrounds, history
- Short description of the DBAM
- Sources of inaccuracy, some reduced by calibration some not
- Review of existing information
  - Rhine
  - Elbe
    (both cases: calibration based on tracer experiments)
- Specific conditions in the Danube Basin
- Synthesis: main options and decisions to be made

Input for present Workshop

icpdr iksd

Danube Regional Project UNDP GEF

Workshop

Objectives

Basic rules

Agenda

Roles and responsibilities

Objectives

- reach agreement about what is necessary to achieve project goals
  (technically sound basis for calibration and future use)

- reach agreement on how this can be done best

Basic rules

.. to be agreed ..

Draft Agenda (part 1)

- Welcome, introduction and agenda
- Availability and utilisation of the DBAM:
  - summary of input from APC/EG members
  - discussion
  - conclusions and recommendations
- Introduction to the DBAM and its history
- Experience from Rhine/Elbe basins (external expert)

WL | delft hydraulics

Draft Agenda (part II)

- Factors affecting the accuracy of the DBAM

- Specific calibration options
  - explanation
  - discussion
  - conclusions

- Closure

icpdr iksd

Danube Regional Project

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Specific calibration options

- Scope and objectives of the calibration
- Availability of existing data and need for additional experiments
- Selection of tracers
- Sampling and analysis
- Density of stations
- Hydrology data
- Organisational aspects

Any comments, amendments??

icpdr iksd

Danube Regional Project

This workshop

Role of Consultant:

1. **Provide background information <u>before</u> discussions**
2. **Either record output from the participants**
   or
   Chair the discussions

   Not both!

Proposal:

participants will nominate chairpersons or reporters among themselves

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Introduction to the DBAM and its history

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Objectives

predicting the travel time of a cloud of pollutants released in the river system as the result of an accidental spill

predicting the concentration in this cloud as a function of space and time

Boundary conditions:

- **large scale events of a trans-boundary nature**
- **first and rapid assessment under operational conditions (the run-time should be short and the necessary input data should be limited)**

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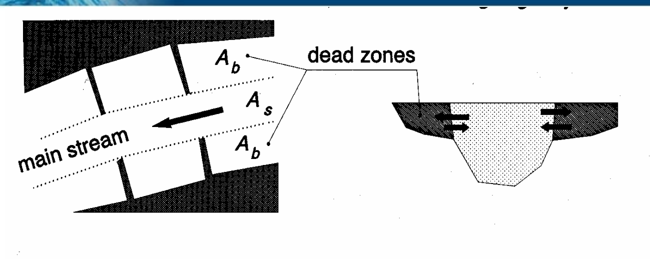
Main features

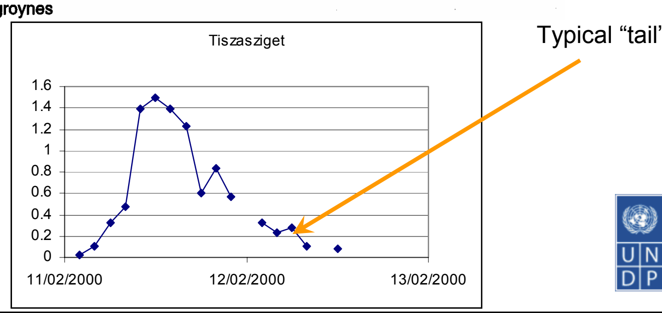
1D approach (suitable for large scale events)

Mathematical "dead zone" model, like Elbe, Rhine, French rivers, etc.



(a) plan view of a river section with groynes

(b) cross section



Main features

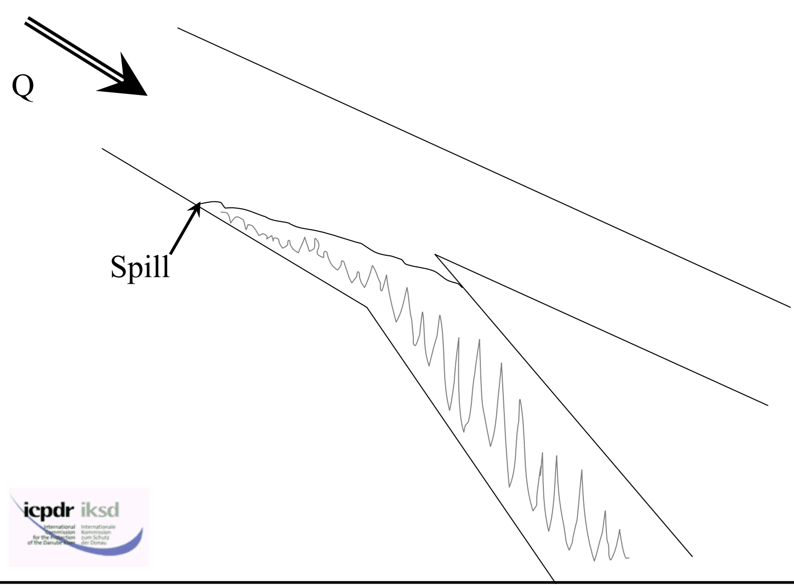
“Analytical” solution technique is applied (direct expression of C(x,t))

- efficient
- accurate

Full mathematical description in the Calibration Options Report (par. 2.2) and references therein

Option to include some 2D effects

- lateral distribution of C
- effect on distribution of mass over bifurcations



1D Analytical solution

C = function of:

- spill mass M
- river discharge Q
- stream velocity V (averaged over cross-section)
- ratio of cross-section in dead zones and cross-section in main stream β
- river width W
- longitudinal dispersion parameter α
- decay rate k of pollutant

Hydraulic parameters

Hydraulic parameters: C(x,t) = function (…,Q,V,W,…)

- discharge Q
- velocity V
- width W

Derived from actual hydrological data (gauge readings, observed discharges) by means of built-in tables:

- Q(H)
- V(H) or V(Q), W(H) or W(Q)

Limited accuracy but a spill event has a duration of many days, and how accurate are hydrological forecasts?

Constant per river reach (quasi-steady)

Main features

Graphical User Interface

- input of data
- presentation of output
- archiving

Input

- spill mass
- spill location
  - (optional: position in cross-section L/M/R)
- spill time
  - instantaneous
  - distributed over certain period
  - C(t) at spill location
- (optional) decay rate
- (optional) floating substance
- water level and/or discharge at relevant hydrological stations

Output

- C(t) at predefined stations, graph and table
- animation in map
- C(t) at location selected from the map, graph and table (resolution about 5 km)
- Cmax along the river, graph and table
- time of Cmax along the river, graph and table

History

Pre-study (1996):

- specifications

Implementation (1996):

- first version of software
- model parameters were given estimated values
- "tracer feasibility study“

Phare Environmental Consortium (1998):

- Methods for Calibration Experiments

History

Strengthening the Danube AEWS (2000):

- second version of software
- verification of built-in tables
- inventory of 1d HD/AD models (as recommended in "Methods for Calibration Experiments")
- evaluation of accuracy on Baia Mare spill
- recommendations for calibration, maintenance

All these references have been discussed in the Calibration Options Report

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Rhine example

- (Much) smaller basin, (much) less countries, different organisational and economical conditions
  but
- Similar “alarm system”
- Similar “alarm model”
- Calibrated on 8 large scale experiments between 1988 and 1991

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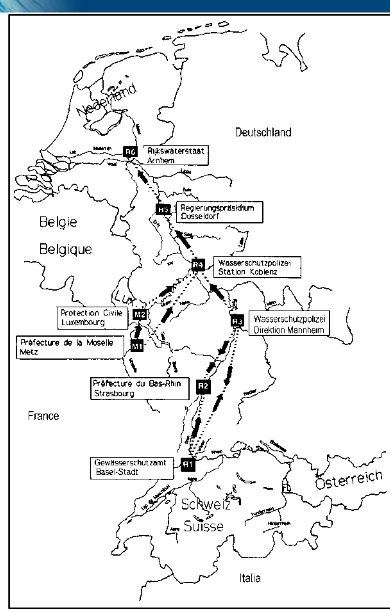

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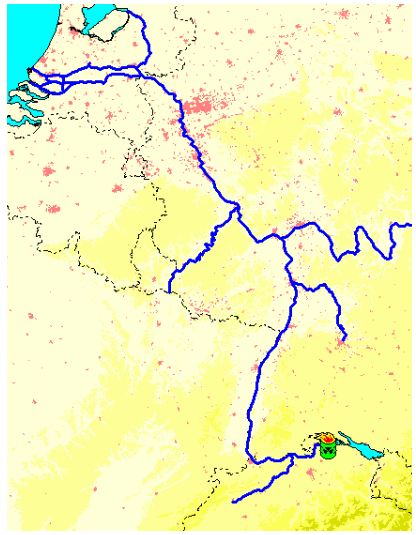
Rhine Alarm Model



Use of the Rhine Alarm Model

- User Group, which meets regularly (low frequency)
- permanent Support Group (representatives of member states), which provides
  - user support
  - technical supervision
- specific modifications and upgrades by consultant

Tracer experiments in the Rhine

Scope and objectives

- focus on large spatial scale
  - longitudinal transport on the main river
  - dissolved substances
- with follow-up studies for details
  - tributaries
  - locks, weirs, dams, reservoirs
  - lateral dispersion phenomena

Existing data or new experiments?

Tracer experiments constituted the “backbone” of the calibration.

Existing data have been used later in a supportive role, to verify the model and to solve detail questions.
Data used:

- accidental spills
- variable chloride concentration

Tracer

- Different fluorescent substances (salt and radio nuclides were rejected)
- 75 to 235 kg per experiment
- Dispersed within 2 to 6 minutes
- Preference for Rhodamine WT (stable, relatively low ecological risk)

Sampling and analysis

- automatic samplers
- brown bottles (to avoid photolysis)
- UV-spectrometry (cheap Synchronscan-method)
- Checks with expensive HPLC method
- Different laboratories

Selection of stations / “observation windows”

- Average distance between stations < 100 km
- Determination of “observation window” unknown
- Lateral position of stations importance (confluences!), usually in the middle of the river from bridges or other structures

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Hydrology data

Several experiments under different hydrological conditions (no floods!)

Recommendation to collect as many discharge data as possible

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Organisation

- jointly by involved institutes and agencies
- all participants paid their own costs for manpower, sampling and analysis

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EASE

EASE

Is a Project of

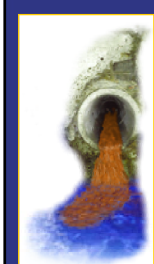
Commissioner

- German Federal Environmental Agency

Contractor

- Institute for Hygienic and Environment
  Free and Hanseatic City of Hamburg, Environment and Health Department
- In assistance with the IKSE

EASE



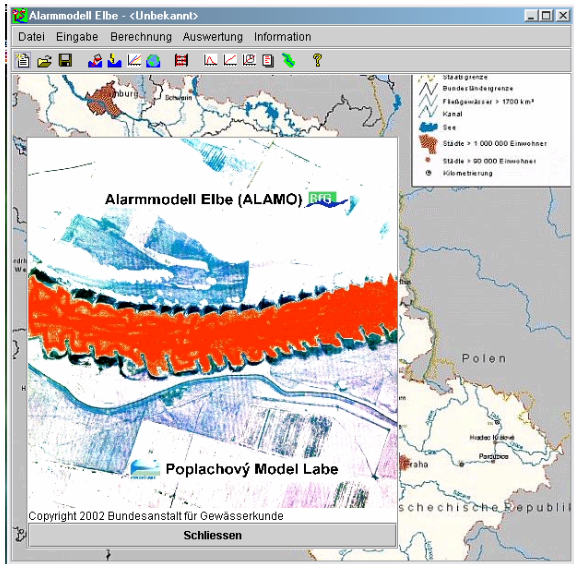
EASE* (Re-) Introduction

- *Project EASE:*
„Development of Alarm Criteria and Detection of Major Incidents in Monitoring Stations located in the Elbe Catchment Area for International Emergency Planing"

* EASE is the short form for the german title of the project. We want to ease the alarm and trouble recognition!

EASE

Alarm model Elbe – ALAMO



EASE

Alarm model Elbe – ALAMO

Elbe catchment area

North Sea

Hamburg

Berlin

Praha

Source

EASE

Alarm model Elbe – ALAMO

- A Simulation software - ALAMO
- ALAMO serves as a model for forecasting the propagation of pollutants in the Elbe

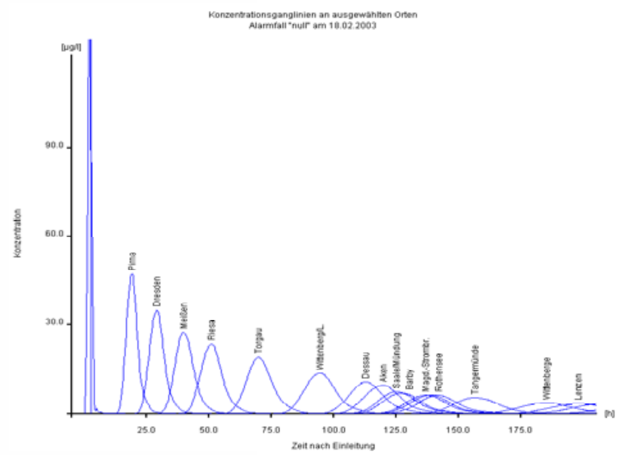
EASE

Main factor to the course of the pollutant wave

- Water levels
- Amount of discharge
- Discharge point
- Discharge time
- Next Alamo demonstration ...

EASE

ALAMO



Course of the pollutant wave

At different places

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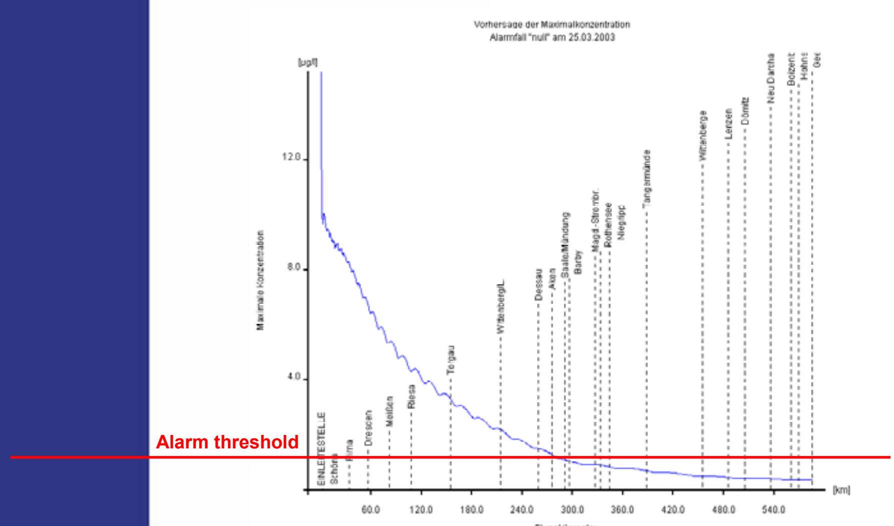
ALAMO



Course of the pollutant wave

Maximum concentration

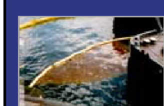
Assessment of major incidents

Agent WRC discharge	Discharge	*[µg/l]	56	82	108	154	214	259	290	332	388	454	484	504	536	559	585
Diethylamin	min	1000															
1	mean	1000															
10.000	max	1000															
Terbutylazin	min	50															
2	mean	50															
1.000	max	50															
Atrazin	min	34															
2	mean	34															
1.000	max	34															
Nitrobenzol	min	10															
2	mean	10															
1.000	max	10															
Etrimphos	min	0,4															
3	mean	0,4															
100	max	0,4															
Trichlorfon	min	0,2															
3	mean	0,2															
100	max	0,2															
Dichlorvos	min	0,06															
3	mean	0,06															
100	max	0,06															

Distance [km]

* Alert level

Assessment of major incidents



Alarm thresholds (draft) derived from quality standards **according to WFD**:

The Alarm threshold for major incidents is calculated using the qualitiy standard (QS) from the wfd muliplied with a factor. In this example the factor is set to 100

Alarm threshold (= quality standard * 100):

Pollutants with QS > 1 µg/l	**: 100 µg/l**
Pollutants with QS > 0,1 µg/l	**: 10 µg/l**
Pollutants with QS > 0,01 µg/l	**: 1 µg/l**
Pollutants with QS > 0,001 µg/l	**: 0,1 µg/l**
Pollutants with QS > 0,0001 µg/l	**: 0,01 µg/l**

Water level [m³/s]	Discharge quantity [kg]	Distance to fall below the alarm threshold for major incidents [km] 100 µg/l	10 µg/l	1 µg/l	0,1 µg/l	0,01 µg/l
2000	1	< 1	< 1	< 1	ca. 10	ca. 100
2000	10	< 1	< 1	ca. 10	ca. 100	ca. 1.000
2000	100	< 1	ca. 10	ca. 100	ca. 1.000	ca. 10.000
2000	1000	ca. 10	ca. 100	ca. 1.000	ca. 10.000	> 10.000
2000	10.000	ca. 100	ca. 1.000	ca. 10.000	> 10.000	>> 10.000
2000	100.000	ca. 1.000	ca. 10.000	> 10.000	>> 10.000	>> 10.000
2000	1.000.000	ca. 10.000	> 10.000	>> 10.000	>> 10.000	>> 10.000

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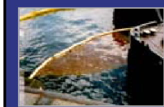

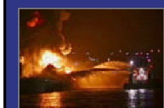

Assessment of major incidents

Alarm thresholds (draft) derived from **IWAE:**

The Alarm threshold for major incidents is calculated as follows:

Alarm threshold:
Pollutants with WRC 0 : 100 µg/l
Pollutants with WRC 1 : 10 µg/l
Pollutants with WRC 2 : 1 µg/l
Pollutants with WRC 3 : 0,1 µg/l

Water level [m^3/s]	Discharge quantity [kg]	Distance to fall below the alarm threshold for major incidents [km]			
		WGK „0“ 100 µg/l	WGK 1 10 µg/l	WGK 2 1 µg/l	WGK 3 0,1 µg/l
2000	100	ca. 10	ca. 100	ca. 1.000	ca. 10.000
2000	1000	ca. 100	ca. 1.000	ca. 10.000	> 10.000
2000	10.000	ca. 1.000	ca. 10.000	> 10.000	>> 10.000
2000	100.000	ca. 10.000	> 10.000	>> 10.000	>> 10.000

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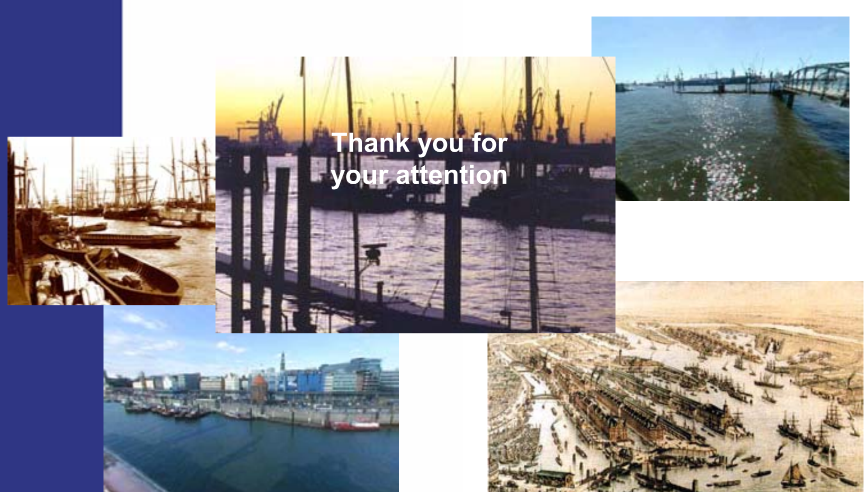
Take a look at the Hamburg Harbour...



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(improvement of) Availability, Utilisation and Accuracy

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Current status: availability and utilisation

Few PIACs are actually using the DBAM, mostly due to:

- software not available
  distribution through Danubis
- software can not be installed
  maintenance provisions needed
- running problems
  maintenance provisions needed

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Extension of functionality

- Input of treshold value, and representation of this value in the output
- Connection to database with substances and treshold values
- Variable time step in output

Conditions for maximum accuracy

Per "phase":

1. hydrology data available under operational conditions
2. rating curves accurate
3. velocity tables accurate
4. DBAM properly calibrated

Accuracy enhancement

How accurate should the DBAM be, in view of its role in the AEWS?

- the stricter the requirements, the higher the costs

Calibration alone is not enough to guarantee accuracy:

- periodic checks on availability of hydrological data under operational conditions
- periodic checks on rating curves and velocity tables

Availability of hydrological data

What is current practice in collecting hydrology data?

Is there any transfer of this information between the countries?

Is there an organisation collecting these data on a Danube wide scale?

To what extent could this information be collected from the web site?

Is it possible to use only predefined conditions for operational use of the DBAM? (high-low-medium)

Rating curves and velocity tables

Organisational aspects

- Who “owns” the data?
- Who will be responsible for maintenance (organisation and finances)?

Technical aspects

- Checks on (recent!) field data? or
- Checks on existing HD models? (and who maintains those?)

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Factors affecting the accuracy of the DBAM

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Overview

Every phase of the calculations has its own inaccuracies:

1. collection of hydrology data
2. calculation of discharges
3. calculation of velocities
4. calculation of concentrations

Inherent inaccuracy from underlying assumptions:

- 1D concept
- quasi-steady hydraulic coefficients Q and V

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Phase 1: Hydrology data

- Spill has a duration of many days (Baia Mare: 4 weeks)
- In "forecasting" mode (operational mode) a forecast of hydrology data is required
- Not available, so
- Hydrology of today = hydrology of coming days/weeks
- Sensitivity analysis

Source of inaccuracy NOT reduced by calibration

(can be checked/eliminated in "hind casting" mode, if sufficient data are available)

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Phase 2: Calculation of discharges

- From built-in rating curves
- Conceptual inaccuracies
- Rating curve can be outdated

Source of inaccuracy NOT reduced by calibration

(can be checked/eliminated in "hind casting" mode, if sufficient flow data are available)

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Phase 3: Calculation of velocities

- From built-in tables
- Conceptual inaccuracies
- Tables can be outdated, or inaccurate

Source of inaccuracy REDUCED by calibration

Phase 4: Calculation of concentrations

Uncalibrated model parameters

- dead zone parameter β, affects
  - travel time
  - concentration
- dispersion parameter α, affects
  - concentration

Source of inaccuracy REDUCED by calibration

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Example Baia Mare

- Hungarian Tisa
- Inaccuracy due to Phase 1 and Phase 2 eliminated, actual time-dependent values of H and Q

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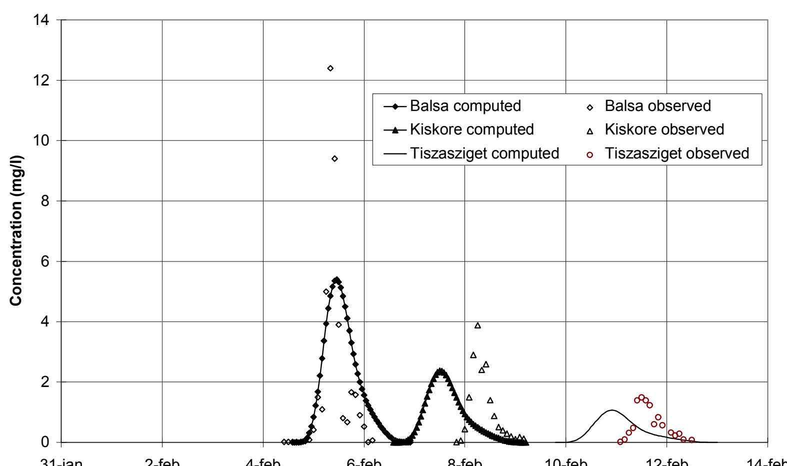

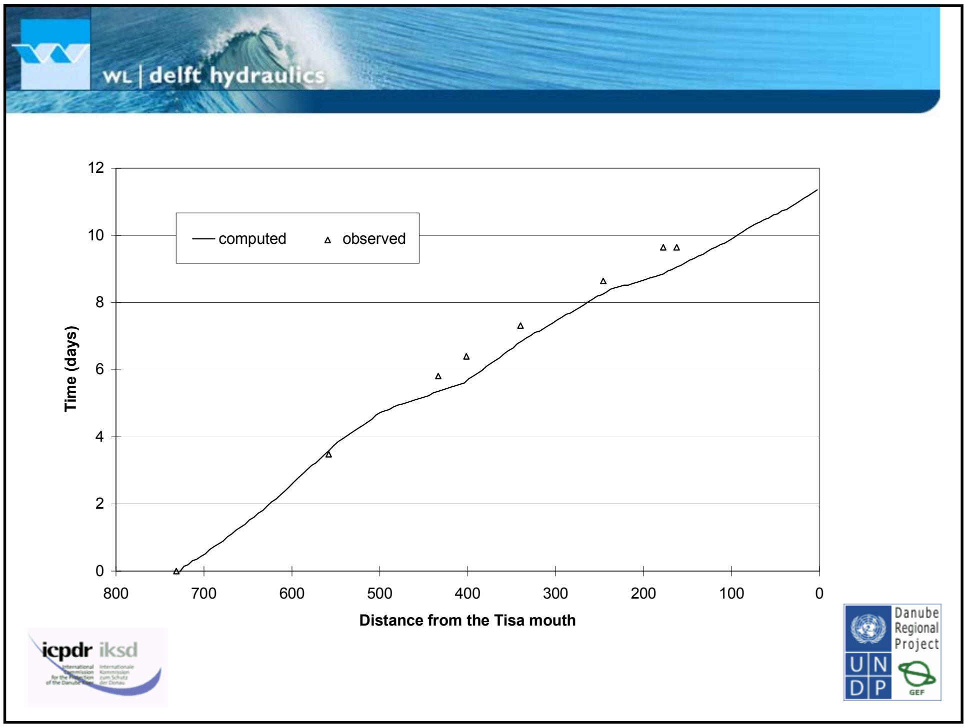
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12
10
8
6
4
2
0
Time (days)
computed
observed
800
700
600
500
400
300
200
100
0
Distance from the Tisa mouth
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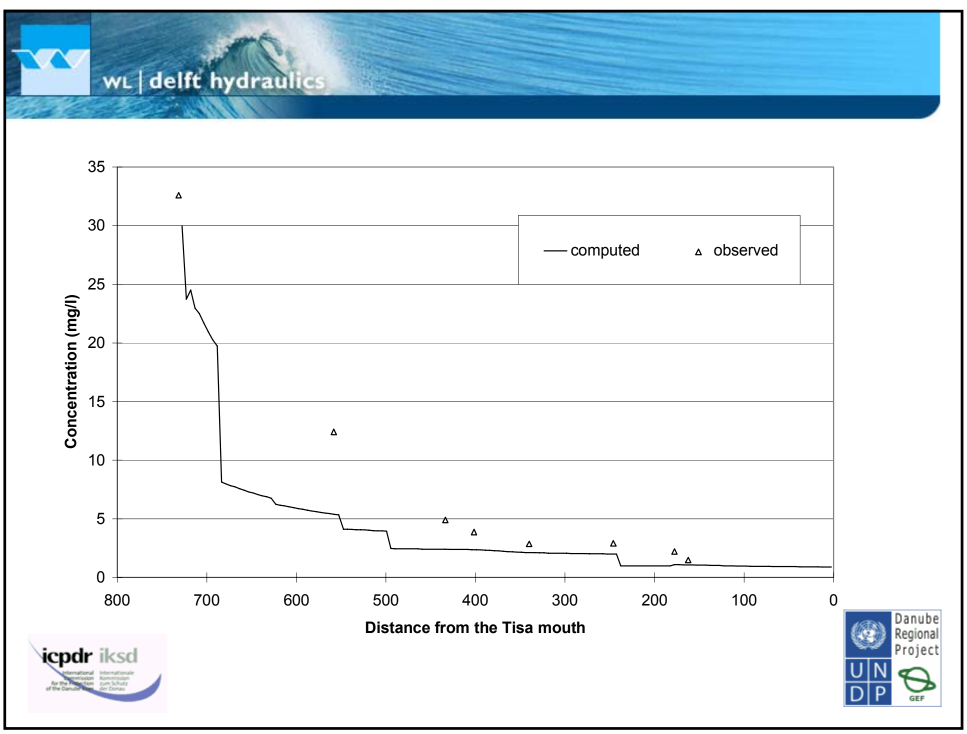
wL | delft hydraulics
35
30
25
20
15
10
5
0
Concentration (mg/l)
computed
observed
800
700
600
500
400
300
200
100
0
Distance from the Tisa mouth
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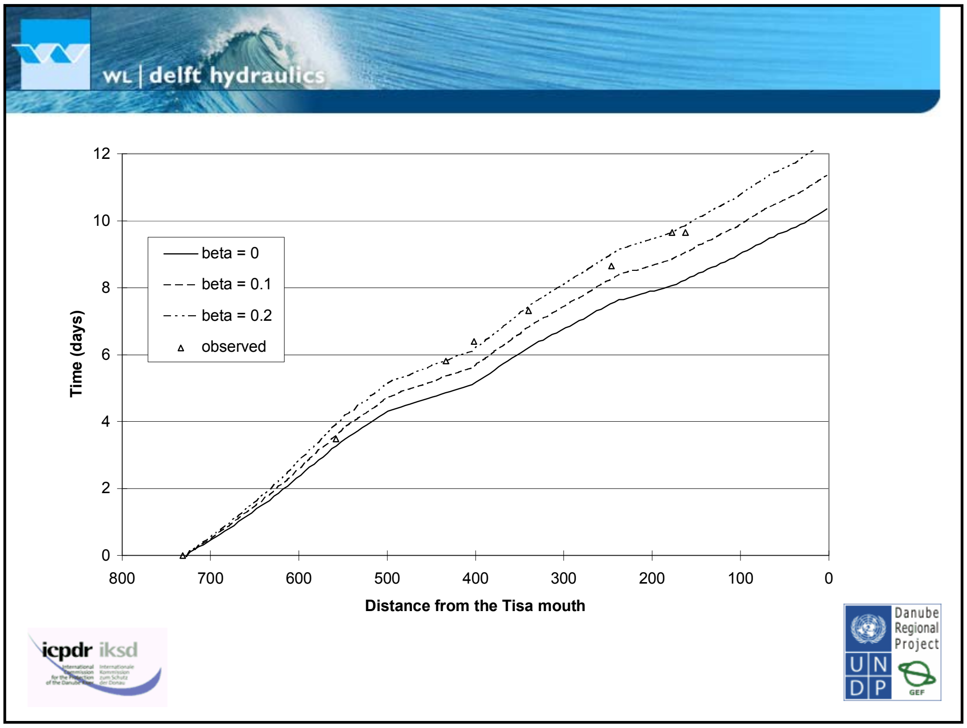
wL | delft hydraulics
12
10
8
6
4
2
0
800
700
600
500
400
300
200
100
0
Time (days)
Distance from the Tisa mouth
beta = 0
beta = 0.1
beta = 0.2
observed
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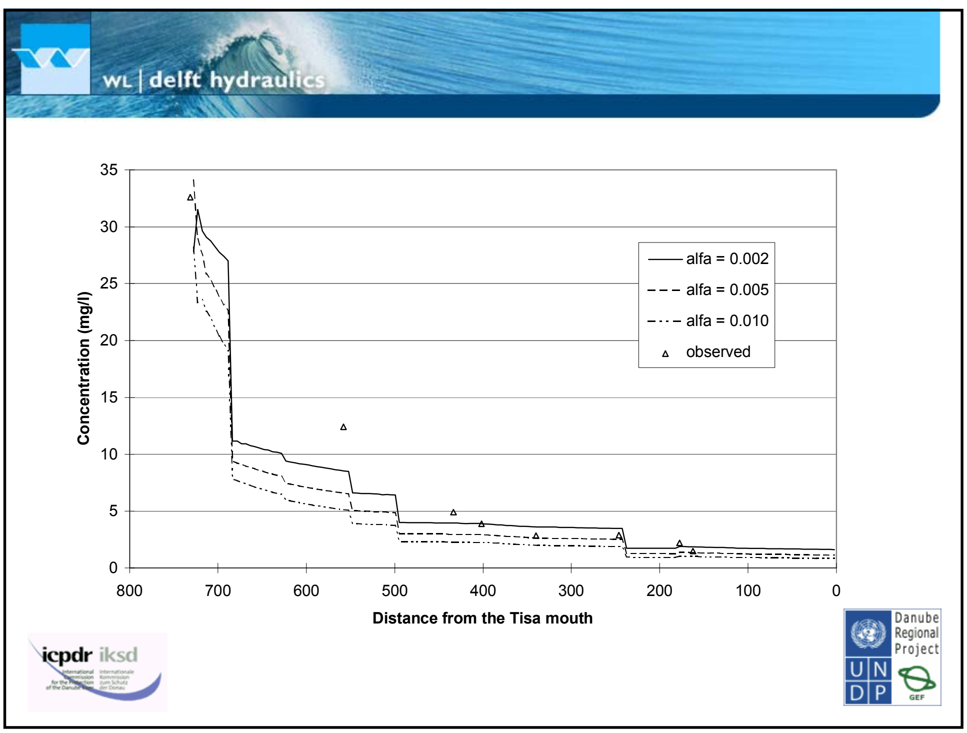
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35
30
25
20
15
10
5
0
800
700
600
500
400
300
200
100
0
Concentration (mg/l)
Distance from the Tisa mouth
alfa = 0.002
alfa = 0.005
alfa = 0.010
observed
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Tisa-Somes river km	Travel time rel. error (%)	Peak Conc rel. error (%)	Danube river km	Travel time rel. error (%)
Somes, 45.4			1072	
Tisa, 558	4	-57	941	-20
433.5	-25	-51	795	-20
340	0	-26	679	25
246	3	-31	597	-4
162.5	-17	-28	495	4
			375	5
			159	-2
	cum. Error (%)			**rel. error (%)**
total stretch	-6		total stretch	-5

Conclusions

- accuracy of travel time unexpectedly good over longer distances:
  - 5% resp. 6% over Danube and Tisa (similar to Rhine Model after calibration!)
- accuracy poor (deviations up to 25%) over shorter stretches
- over longer distances the errors are non-systematic and tend to compensate each other

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Conditions for maximum accuracy

Per “phase”:

1. hydrology data available under operational conditions
2. rating curves accurate
3. velocity tables accurate
4. DBAM properly calibrated

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Calibration options

A Scope and objectives?
B Existing data or new experiments?
C Selection of tracers
D Sampling and analysis
E Density of stations
F Hydrology data
G Organisation

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Scope and objectives

Trans-boundary objective of AEWS:

- focus on large spatial scale: Danube and large international tributaries,
- with follow-up studies for details
  - smaller tributaries
  - locks, weirs, dams, reservoirs
  - lateral dispersion phenomena

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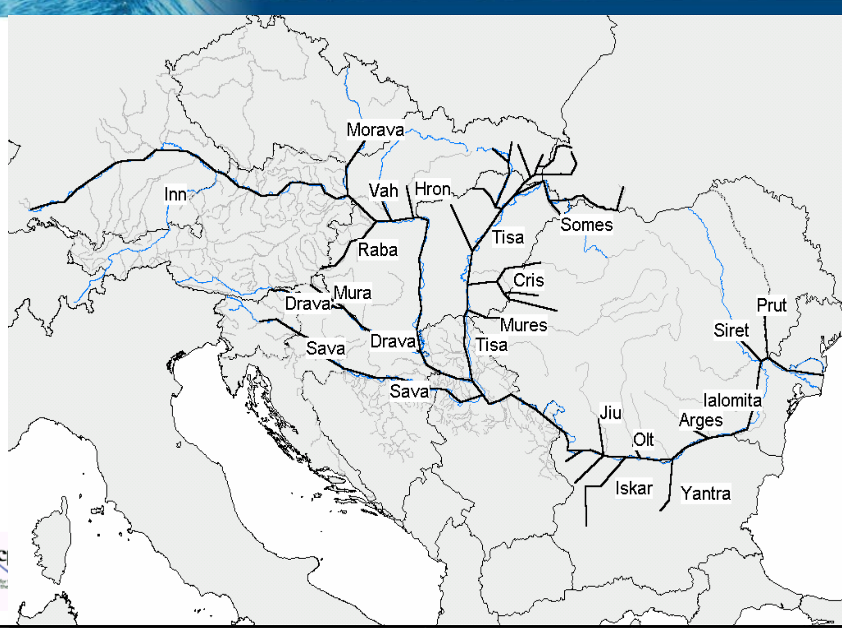
Scope and objectives

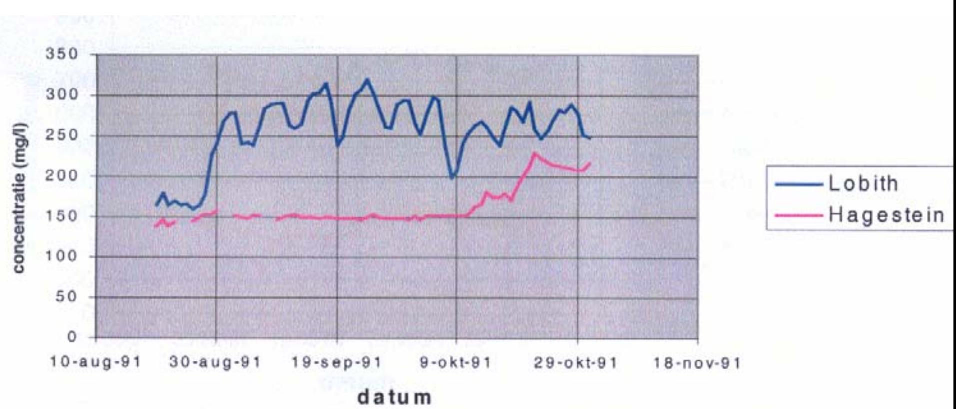
- Is there agreement about the scope and objectives?
- Which international tributaries to include?
- With what prioritisation?
  (driven by presence of hot spots??)



Existing data or new experiments?

- Tracer experiments are costly, and existing data can present a cheaper alternative:
  - spills from the past
    - Baia Mare
    - Croatian Danube
    - …
  - "normal" parameters showing strong temporal trends
    - …
  - existing tracer experiments
    - Sava in Slovenia
    - …

Example



Existing data

- C(t) at 2 or more stations
- Detailed hydrology data available (space and time)

To what extent are such data available??

Selection of tracers

Salt	Cheap, low impact	Very high dosage
Radio nuclides	Very high sensitivity, proven technology, in-situ analysis	Legal restrictions?
Fluorescent tracers (rhodamine etc.)	High sensitivity, proven technology, in-situ analysis	Ecological impacts? Legal restrictions?
"Natural tracers"	Low impact	Experimental technique (feasibility study first!)

Selection of tracers

- Inventory of legislation already available (1998). Need to verify!

Sampling and analysis

Relying on in-situ observations only not possible (Elbe and Rhine)

Recommendations laboratory analysis:

- analysis soon after sampling
- analyses in one laboratory

Not feasible in view of the large size of the Danube basin!

Sampling and analysis

"Central"
- one central laboratory
- long transport time
- no consistency problem between lab's

"Decentral"
- different laboratories
- short transport times
- possible inconsistencies between lab's

Selection of stations and "observation windows"

- Stations should be carefully selected (recommendations from Rhine and Elbe)
- High or low density of stations?

Density of stations

High density
- distance < 100 km
- spatial variation of calibration parameters well-resolved
- less experiments for same budget

Low density
- distance > 100 km
- spatial variation of calibration parameters not so well-resolved
- more experiments for same budget:
  - different flow regimes
  - different tributaries

Hydrology data

Preferably, several experiments under different hydrological conditions (no floods!), but anyhow:
- Full daily records at all stations during the experiments
- If possible, simultaneous observation of water level and discharge!

Any organisational recommendations??

Organisation

- national institutes and agencies having equipment and laboratories should be involved
- important role for MLIM / TNMN
- a central (small) planning and co-ordination group?

Agreement?
Other recommendations?

C List of attendants to the Workshop

Name	Position
Aurel Varduca	APC/EG member Romania, Chairman
??	APC/EG member Bulgaria
Daniel Geisbacher	APC/EG member Slovakia
Janez Polajnar	APC/EG member Slovenia
Jovanka Ignjatovic	APC/EG member Serbia & Montenegro
György Pinter	APC/EG member Hungary
Beata Pataki	future APC/EG member Hungary
Pavel Biza	APC/EG member Czech Republic
Nena Hak	APC/EG member Croatia
Igor Liska	ICPDR Permanent Secretariat
Ivan Zavadsky	DRP, Project Manager
Alex Hoebart	DRP
Werner Blohm	Institut für Hygiene und Umwelt, Hamburg city

D Inventory "availability and utilisation of the DBAM" (G. Pinter)

QUESTIONNAIRE ON THE AVAILABILITY AND UTILIZATION OF THE DANUBE BASIN ALARM MODEL

at the PIACs of the Danube AEWS

Final version

PIAC No.	Latest version of DBAM (2.00.02) available	Number of PCs to use DBAM in PIAC	Operation system of PCs using DBAM	Conditions of USING DBAM	Detailed description of problems in DBAM operation	Remarks
01	No (Version 1.01 available)	1	Windows NT 4.0	Not in use		
02	No	-	-	Not in use		
03	Yes	2 PC 1: P4, 1.7 GHz, RAM 256 MB, HDD 60 GB PC 2: P II, 400 MHz, RAM 128 MB, HDD 16 GB	PC 1: Windows 2000 PC 2: Windows 98 SE	PC 1: Not working PC 2: Working	PC 1: DBAM installed, but the mathematical model is not working. Error message: „Error while running the mathematical model".	
04	Yes	PC 1: P VI, 400 MHz, RAM512MB, HDD 40 GB (??)	PC 1: Windows 2000	PC 1: Not working	PC 1: DBAM installed, but the mathematical model is not working. Error message: „Error while running the mathematical model". When DBAM is used under WIN´98 it runs satisfactorily.	It seems that problem will be in system. Installation DBAM in new PC with WINDOWS 2000 it does not work.
05	Yes	2 PC 1-2: P 4, 2,4 GHz, RAM 512 MB, HHD 40 GB	Windows XP Professional	Problems, not working	PC 1-2: Installation of DBAM is refused. Error message: „You can not install this VB5 application without the latest service pack first being installed onto this computer". This is a strange message, because the existing operation system of these computers is the latest version, updated with all the possible, and necessary components !!!	Interesting to note, that on a home computer (Gy. Pintér) having WIN98, the DBAM is running smoothly, installed by the same original CD from Delft Hydraulics (PIII. 860 MHz, 256 MB RAM)
06	Yes (only the old version!!)	2 PC 1-2	Windows 2000	Not in use	Problem of installation: lack of Netter Set-up program	Remarks on the problems of using the older version of DBAM

PIAC No.	Latest version of DBAM (2.00.02) available	Number of PCs to use DBAM in PIAC	Operation system of PCs using DBAM	Conditions of USING DBAM	Detailed description of problems in DBAM operation	Remarks
						has been sent to Mr. Jos van Gils in 2000.
07	?				No response from Croatia	
08	No (just DBAM version 1.01)	1 Pentium 75 Mhz, 640 kB memory (?)	Windows 3.1	Working very well	DBAM is installed, but since the 2001 Cyanide spill accident was not used due to no any major pollution recorded on Danube basin, downstream of the inner river reservoirs. Anyway, still remain the major problem of DBAM version 1.01, the prognosis of the pollution plume movement which is ahead of 24 hours than the reality.	It is very important to acquire the new version of DBAM (2.00.02) which can work also on Windows 98 or XP on the new acquired PC (Pentium 4).
09	Yes	2 Pentium IV, 2,4 GHz , 512 RAM	Windows 2000 Pro	Problems, not working	PC No.1: DBAM installed, but the mathematical model is not working. Error message: „Error while running the mathematical model" PC No.2: Installation of DBAM is refused. Error message: „You can not install this VB5 application without the latest service pack first being installed onto this computer".	On a computer having WIN98 (Pentium II 266 MHz, 64 MB RAM), the DBAM is running without any problem.
10	?				No response from Moldova	
11	?				No response from Ukraine	
12	?				No response from Ukraine	
S&M	No	-	-	Not in use		

Original text of the e-mail when the Questionnaire have been first sent to AEP-EG members on 13.05.2003 is as follows:

„Dear APC-EG members,
Few years ago the revised version of the Danube Basin Alarm Model (DBAM) has been forwarded to the Expert Units of the PIACs of the Danube AEWS for utilisation in practice. Due to changes in the meantime in hardware and software facilities at the PIACs, there are some problems with the installation and running this model-system. Especially we face problems with the operation of the DBAM at PIAC-05 in Budapest.

Recently the "father" of the revised DBAM, Mr. Jos van Gils visited VITUKI for other purposes, but we were lucky to have a rather long discussion with him about DBAM-problems. Studying the errors in the site unfortunately improvement could not be done immediately, but he promised to solve directly these problems, like what they have done with the similar problems of the Rhine Alert Model.

For this purpose it is necessary to collect all the experiences of the PIACs in the Danube Basin concerning the operation and problems of the DBAM model-system, which will be the forwarded to Mr. Jos van Gils. Please forward the enclosed questionnaire to the Expert Unit of your PIAC, asking them to provide their experiences, and send it back to me within a month, if possible. This action is made with the agreement of Mr. Igor Liska from ICPDR Secretariat.

Looking forward to your reply, and please do not hesitate to improve the enclosed table, if it seems to be necessary,
Best regards
György Pintér”

(Date of inserting the latest incoming information is: 12. August 2003.) Compiled by: Gy. PINTÉR, APC-EG.

E Draft ToR for maintenance of the DBAM

(Copied from Hartong (2000).)

Objectives

The maintenance of the Danube Basin Alarm Model (DBAM) needs to be carried out with the following objectives in mind:

- *archiving*: to guarantee that all existing and future versions of the software, the data files and the documentation are at any time available to anyone making a legitimate request;
- *support*: to provide a so-called “Helpdesk facility” for recognised users of DBAM;
- *upgrades*: to create periodic upgrades of the software, the data files and the documentation.

The technical and scientific responsibility with respect to the DBAM resides with the AEPWS Expert Group (APC-EG) under the International Commission for the Protection of the Danube River (ICPDR). The administrative responsibility in this respect lies with the Permanent Secretariat (PS) under the ICPDR.[2]

Tasks

1 Archiving

The Consultant shall keep duplicated electronic records of all existing and future versions of the software, the data files and the documentation, as well as all other files and documents relevant to producing versions of the DBAM. The records will be made on CD-ROM. The Consultant shall take into account the life time of the information holders specified by the manufacturers and will take care that new copies are made timely.

The archived material will be made available to any of the recognised users of the DBAM and to any one whose request is approved of by the PS. The latter type of requests are supposed to be very rare.

The Consultant will keep records of all supplied copies.

2 Support

The Consultant will operate a Helpdesk service by email. Questions related to the use or the functioning of the DBAM software will be answered within a reasonable time. The Consultant will guarantee the scientific and technical soundness of his answers by consulting experts appointed by the AEPWS-EG.

The Helpdesk services will be available to any of the recognised users of the DBAM and to any one whose request is approved of by the PS. The latter type of requests are supposed to be very rare.

The Consultant will keep records of all requests for support and register the amount of time spent on answering the questions.

3 Upgrades

[2] *These responsibilities should be precisely defined in the final ToR. The current text should be considered indicative only.*

3.1 Analyse reported shortcomings of the DBAM

If certain shortcomings of the DBAM or its documentation are reported (through the Helpdesk services or directly through the PS or the AEPWS-EG), the Consultant shall analyse them, shall decide how they can be removed and shall estimate the costs. The Consultant will guarantee the scientific and technical soundness of his decisions by consulting experts appointed by the AEPWS-EG.

Depending on the cost estimate either task 3.2 or task 3.3 will follow.

3.2 Carrying out small changes

If the repairs or changes related to certain shortcomings analysed in task 3.1 are small, the Consultant will carry them out. After every change, the proper functioning of the DBAM will be tested. Tests and their results will be registered.

The Consultant will keep records of all repairs made and register the amount of time spent on each action.

3.3 Provide definitions and cost estimates for larger changes

If the repairs or changes related to certain shortcomings analysed in task 3.1 are not small, the Consultant will provide a formal definition of the repairs or changes, including a test plan, and an associated cost estimate.

The PS decides if the defined changes need to be carried out (and by whom), and if so, makes available the necessary finances.

3.4 Formally accept all changes made outside the Maintenance contract.

It is possible that certain changes are carried by other parties than the Consultant carrying out the Maintenance contract. Such changes always need to be based on an officially archived version of the DBAM. The updated versions need to be formally accepted by the Consultant carrying out the Maintenance contract. The Consultant will do so based on written design and test reports and by explicitly inspecting the changes.

3.5 Integrate all changes into upgrades or releases

The Consultant will create periodic upgrades of the DBAM, by taking the previous release and integrating all changes made under tasks 3.2, 3.3 or 3.4.

The new release will be tested. The Consultant will write a test report and submit this to the AEPWS-EG or any person(s) nominated by the EG for approval. Finally, the upgrade is officially distributed to the users of DBAM.

Inputs

- Existing software, data and documentation.
- List of recognised users.
- Names and addresses of nominated DBAM experts to advise the Maintenance responsible..

Outputs

- Archives of software, data and documentation.
- New releases of software, data and documentation.

- The Consultant will submit 4-monthly reports of activities, and report the costs made for tasks 2, and task 3.1 to 3.4.

Financial arrangement

It is suggested to arrange the finances of the Maintenance contract as follows:

- The contract is made on a yearly basis.
- For task 1 there is a yearly fixed budget.
- For task 2 there is a yearly budget limit, but the Consultant is paid for the real costs up to the specified limit. The periodic reports by the Consultant should guarantee that the Maintenance Services do not have to be stopped unexpectedly due to budget shortages.
- Tasks 3-1 to 3-4 are arranged as task 2.
- For task 3-5 there is an agreement about the number of releases or upgrades (e.g. 1 per year) and there is a yearly fixed budget.

F Suggested extension of functionality

In the present practice of handling accidental spills the notion of a “threshold value” plays an important role. The DBAM could be tailored to support this practice, by:

- allowing the input of the threshold value;
- representation of this value in the output.

Optionally, a connection could be made to a database with substances and threshold values.

Furthermore, the fact that the present DBAM has a fixed time step in its output is considered a problem. In the smaller tributaries, the time dimension should be resolved much finer (minutes) than in the Danube and its main tributaries (hours).

G Existing data inventory

Inventory of existing data still needs to be made with input from APC/EG members. The APC/EG members need to provide written information, including an assessment of the reliability of the data.

H Legislative aspects in relation to tracer experiments

An inventory regarding legal constraints has been made by the Phare Environmental Consortium (1998). This inventory revealed that for all investigated tracer substances (including salt, fluorescent tracers and radio nuclides) the application was subject to specific permitting by the responsible authorities. The conclusion was drawn on the basis of information from Hungary, Slovakia, Czech Republic and Slovenia. For the remaining countries no information was collected at the time.

Although this information still needs to be checked by the APC/EG members, and relevant additions in relation to radio nuclides should still be obtained from IAEA representatives, we can safely assume that a specific permitting step will be necessary for any future tracer experiment.

Given the river geometry and its hydraulic characteristics, a tracer should be selected which is stable enough, has a sufficiently low detection limit and a sufficiently high MAC. The formulas in Appendix I can than be used to estimate the required tracer mass, and to quantify the distance of exceedence of the MAC. Such an analysis can be technical input to the permit request.

I Guidelines for tracer mass calculation and exceedance of MAC

The guidelines presented below are set up assuming that the behaviour of the cloud of pollutants can be approximated neglecting the dead zone effect. In that case the analytical solution to the governing equations is given by the Taylor model:

$$c(x,t) = \frac{M\ /\ Q}{\sqrt{4\ \pi\ D\ t/U^2}} \times \left[\exp\left[\ -\frac{(\ t\ \text{-}\ x/U\ \ )^2}{4\ D\ t/U^2}\ \right] \right] \times \exp(-kt) \qquad \text{(I.1)}$$

With:

$$D = \alpha \frac{U^2 W^2}{h\, u_*}, \quad u_* \approx \frac{U\sqrt{g}}{25 \times \left(\frac{h}{0.2} \right)^{1/6}}, \quad \alpha = 0.002 - 0.010$$

Where:

c	concentration (g/m^3)
M	spilt mass (g)
Q	river discharge (m^3/s)
U	mean flow velocity (m/s)
D	longitudinal dispersion coefficient (m^2/s)
k	decay rate (1/s)
t	time (s)
x	distance from point of discharge (m)
W	river width (m)
h	river depth (m)
g	gravity constant (m/s^2)
α	constant of proportionality

I.1 Estimation of the required mass of tracer

In this case, we use equation (I.1) including the decay factor. The Taylor formula predicts that the maximum concentration at a position x is obtained at t=x/U, which is equal to the hydraulic travel time.

Substituting this, we obtain:

$$c_{\max}(x) = \frac{M / Q}{\sqrt{4\,\pi\,D\,x/U^3}} \times \exp\left(-\frac{kx}{U}\right) \qquad \text{(I.2)}$$

Next, we formulate a condition which ensures that a cloud can be sampled and analysed:

$$c_{\max}(x) > \phi \times c_{\text{det.lim.}}, \quad \textit{with}\ \phi = 10 - 100 \qquad \text{(I.3)}$$

This relation states that the maximum concentration should exceed the detection limit by at least a factor ϕ. By substitution, we can derive the required tracer mass as a function of the river characteristics, of the detection limit and of the distance x of the experiment:

$$M = \frac{\phi \times c_{\text{det.lim.}} \times Q \times \sqrt{4\,\pi\,D\,x/U^3}}{\exp\left(-\frac{kx}{U}\right)} \qquad \text{(I.4)}$$

I.2 Estimation of the distance where concentrations exceed the MAC

If the maximum allowable concentration MAC (g/m^3) is known, the distance over which this concentration is expected to be exceeded can be estimated by solving equation (I.3) for x. For simplicity reasons, we neglect the decay factor. This is a "worst case" approximation. The result is:

$$x_{c>MAC} = \frac{M^2\,U^3}{Q^2 MAC^2\,4\,\pi\,D} \qquad \text{(I.5)}$$

I.3 General considerations

While using these formulas, the following should be kept in mind:

- While estimating the necessary tracer mass (by formula I.4) in a river with non-homogeneous characteristics, the river characteristics should be taken from the downstream end of the river stretch under investigation. Near that position, the dilution is the strongest and the concentrations are the lowest.
- While estimating the distance where the MAC is exceeded (by formula I.5) in a river with non-homogeneous characteristics, the river characteristics should be taken from the upstream end of the river stretch under investigation. Near that position, the dilution is the smallest and the concentrations are the highest.

- The formulas should anyhow be used with a certain margin (10-30%), since the dead zone effect was neglected while deriving them.
- Alternatively, the DBAM itself can be used to obtain estimates which take into account the variable river characteristics and the dead zone effect.

J Guideline for frequency of sampling

The guideline presented below is set up assuming that the behaviour of the cloud of pollutants can be approximated neglecting the dead zone effect. In that case the analytical solution to the governing equations is given by the Taylor model (equation I.1).

In this case we derive a guideline for the sampling frequency by:

- estimating the length of the cloud by calculating the period of time that a certain threshold concentration ξ x C_{max} is exceeded (e.g. $\xi = 0.05$ or 0.10);
- establishing the number of samples N necessary to adequately capture the shape of the cloud (e.g. N = 20).

The result is:

$$\Delta t = \frac{4}{N} \sqrt{\frac{Dx}{U^3} \ln \xi} \tag{J.1}$$

While using this formula, the following should be kept in mind:

- In a river with non-homogeneous characteristics, the river characteristics should be representative for the average conditions between the discharge and observation points.
- The formula should anyhow be used with a certain margin (10-30%), since the dead zone effect was neglected while deriving it.
- Alternatively, the DBAM itself can be used to obtain the estimated time of passage of the cloud, taking into account the variable river characteristics and the dead zone effect.

K Outline of Calibration Manual

The calibration manual should consist of the following elements:

- Description of available data[3].
- Calibration methodology.
- Processing of available data.
- Calibration process.
- Reporting.
- Upgrading the DBAM.

These elements will be further explained below.

K.1 Description of available data

The available data can be either:

- A continuous record of the concentration of a “regular” water quality parameter which shows a strong temporal gradient.
- A concentration record from an accidental spill.
- Concentration records from a tracer experiments.

The data description should include at least the following aspects:

- Introduction.
- Source(s) of information.
- Sampling locations, including an assessment of possible lateral concentration gradients.
- A description of the characteristics of the river stretch in question: geometry, hydrology, structures.
- Sampling frequency, including an assessment of the suitability for full or partial calibration (see below).
- Availability of complete records of the hydrology data at the relevant DBAM stations, as a function of time.
- Explicit reporting of all raw data.

K.2 Calibration methodology

The calibration methodology should be based on a sound understanding of the principles of the DBAM and the sources of inaccuracy of the DBAM, as laid out in Chapter 2. Furthermore, the calibration methodology should be guided by the quality and amount of the available data.

[3] *The manual does not include the collection of data.*

In some occasions, only information about the travel time of pollutants can be derived from the data. In that case only a "partial" calibration can be carried out, which uses the space dependent parameter β to tune the travel time. It should be noted that records of the concentration of a "regular" water quality parameter showing a strong temporal gradient can only be used for this partial calibration.

In other occasions, full information about the precise shape of the cloud can be obtained from the data. In that case a full calibration can be carried out. Scientific publications (e.g. Schmid, 2002 and van Mazijk et al. 2003) should be used to derive an approach allowing separately:

- The checking of the average velocity U in the main stream, as derived by DBAM from its built-in tables.
- The calibration of the space dependent dead zone parameter β and the dispersion parameter α.

Details of the methodology will depend on the availability of data. It is recommended to use an objective parameter optimisation method rather than expert judgement alone.

It is of the utmost importance that the methodology is clearly laid out for later reference.

K.3 Processing of available data

The processing of data is done in line with the methodological requirements. Full reporting to ensure reproducibility is required.

K.4 Calibration process

The calibration process itself is done in line with the methodological requirements. Full reporting to ensure reproducibility is required.

The process should be carried out using full time dependent hydrology input data. This ensures that the variation of the hydraulic coefficients Q and U of the DBAM vary correctly along the river during the propagation of the cloud of pollutants.

The DBAM has a hidden feature which allows the expert user to inspect the resulting hydraulic coefficients. If a file with the name DODEBUG exists on the MODEL directory, the program writes an echo of its input as well as intermediate results to a file called DBAM.DBG.

K.5 Reporting

The reporting should include all steps of the calibration. It should contain a clear and complete record of all data and methods.

K.6 Upgrading the DBAM

The calibration process results in an updated file with numerical coefficients for the DBAM. This file should be handed over to the person or organisation that is responsible for the maintenance of the DBAM. A new version should be issued and distributed.

K.7 References

Schmid, 2002: Persistence of Skewness in Longitudinal Dispersion Data: Can the Dead Zone Model Explain it After All? Bernard H. Schmid, Journal of Hydraulic Engineering, **128**, No 9, 2002.

Van Mazijk et al., 2003: Tracer experiments in the Rhine Basin: Evaluation of the skewness of observed concentration distributions. A. van Mazijk, E.J.M. Veling, in preparation.