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TIME OF TRAVEL STUDIES: AVERAGE AND HIGH FLOWS RIVER OCK

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May 1993

Time of Travel Studies: Average and High Flows for the River Ock

Table showing the velocity of the tracer for each stretch at average and high flows and for average and peak arrival time

Reach			Average Flow Conditions				High Flow Conditions			
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East Hanney	Venn Mill	3.70	227	229	27.17	26.93	235	238	26.24	25.91
Venn Mill	Marcham	3.10	262	266	19.72	19.42	245	247	21.09	20.92
Marcham	R.Thames	4.79	449	452	17.78	17.66	318	315	25.10	25.34

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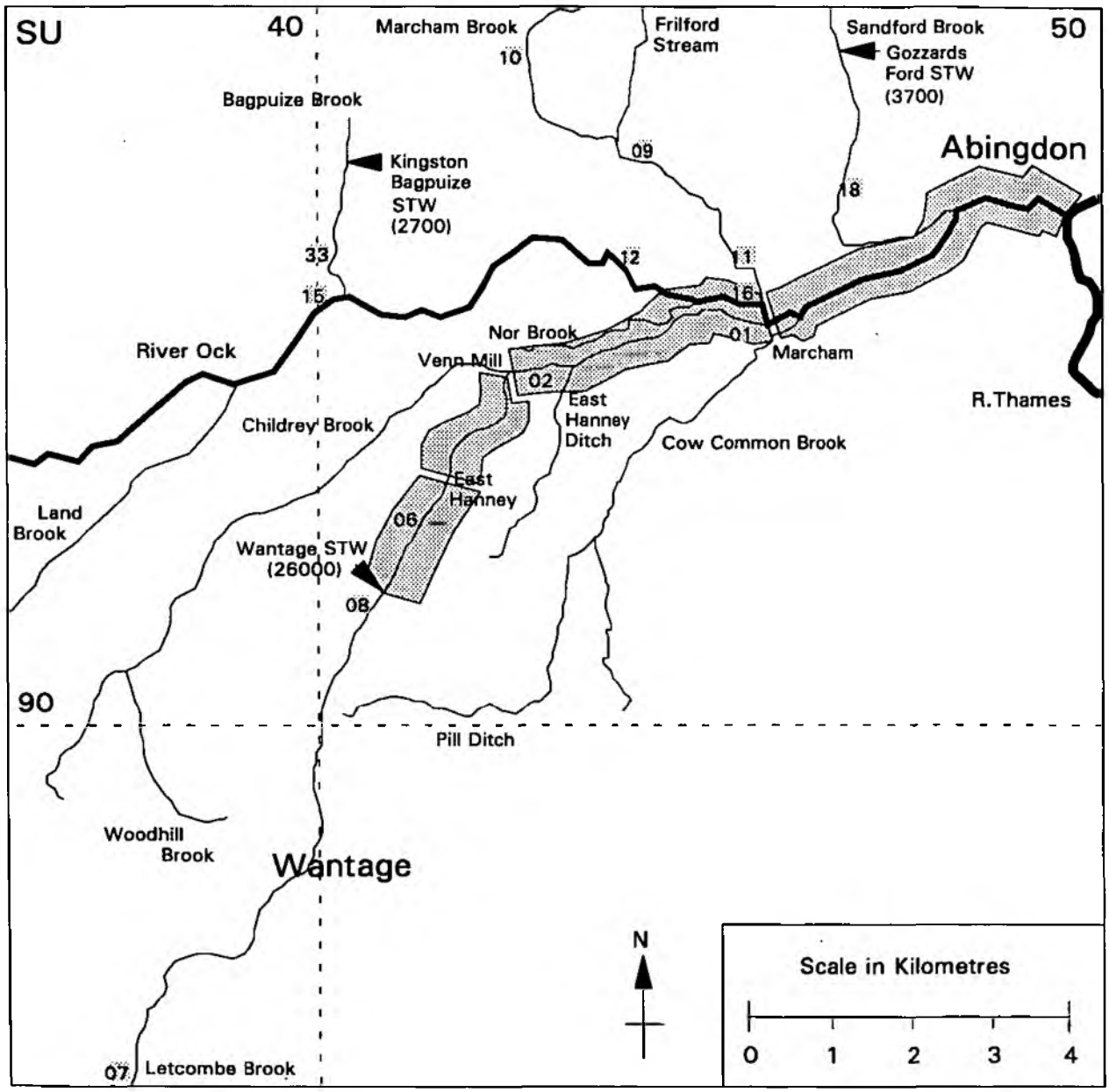
Map showing the location of rivers, sampling points, sewage treatment works and reaches used in the Ock time of travel study.



Key:	Sampling point (Number represents the last two numbers in URN i.e. POCR.0008)	National Grid Reference	Sewage Treatment Work	River	Reach used in time of travel study
	08	90	Kingston Bagpuize STW (2700)		

1 Introduction

This report was prepared by Consultancy Services, AEA Technology, and addresses NRA's requirement to measure the 'time of travel' for both average and high flow conditions in specified reaches of the River Ock.

Rhodamine WT was used as a tracer in determining water's travel time, in terms of the time of first arrival, peak arrival time and the average time for a labelled plume to pass specified reaches of the River Ock. The results are based on measurements made during the dry period 3rd to 11th March 1993 for the average flow, when there had been little rainfall since the very wet January. The measurements involving high flow conditions were made on the 15th and 16th of April after a very wet Easter. The dates for carrying out the studies were agreed with the NRA.

2 Technical Details

2.1 Tracer Release Protocol

A solution of Rhodamine WT in 10 litres of water was introduced into the river at mid stream and/or where maximum turbulence existed. To ensure a rapid mix this was done by emptying the container within a very few seconds.

The amount of tracer that needs to be added depends upon the potential dispersion of the dye between release and sampling point, the concentration on sampling having to be high enough to give a clear definition of the first and the peak arrival of the tracer. We assumed the length of dispersion to be 10% or more of the travel distance, and thus the amount of tracer used in each measurement was based on a volume of diluting water that allowed a dispersion of 10% of the travel distance, aiming at a concentration of tracer on sampling of maximum 20 ppb. For this purpose, the mean depth and width was estimated by wading the river at the measuring points. The dilution of the tracer by confluence to other water courses further downstream, and the additional dilution that takes place at the confluence to the River Thames at Abingdon, ensured a concentration of Rhodamine WT below drinking water standard in the River Thames.

2.2 Tracer Sampling Protocol

The reaches assessed were listed in table 4 of the Tender Document and are shown in table 1. A separate addition of tracer was made for each fetch. At each measuring point water was sampled and monitored for presence of Rhodamine WT. The water was collected midstream or where the flow rate was highest to ensure that the exact time for the first arrival of the tracer was measured. Sampling was from 0.15m below the water surface at a rate of 18 l/min, and a subsample was then removed at a rate of 7ml/min and fed through a flow cell positioned in the spectro fluorimeter sample compartment and continuously analysed for presence of Rhodamine WT. The system is illustrated in figure 1.

The spectro fluorimeter was calibrated by filling the flow cell with a solution of 40 ppb Rhodamine WT. The out put from the fluorimeter was recorded every 15 seconds on a data logger, and a chart recorder was used to allow the operators to monitor the progress of the measurement.

3 Notes on the reaches

3.1 East Hanney

The reach being assessed is Letcombe Brook from Above Wantage STW to the Weir Farm at East Hanney. The tracer was added from a bridge at grid reference SU407 916, and sampled at the bridge in front of the Weir Farm in East Hanney, grid reference SU413 926, figure 2.

3.2 Venn Mill

The reach being assessed is the Letcombe brook from Weir Farm, East Hanney and then Childrey Brook to Venn Mill, grid reference SU430 949. The tracer release point was the same as the tracer sampling point at East Hanney. At Venn Mill the Childrey Brook splits in two parts, of which one takes most of the water round the Mill, as illustrated in figure 3. This results from a recent manmade blockage ensuring that not much water is arriving at the mill. At first, sampling was carried out at the bridge at the mill itself, but about 60 meters further down stream in the garden of The Mill House another blockage appears. This second blockage resulted in the failure of live attempted measurements, when tracer was added at Venn Mill for sampling at

Marcham, see also section 3.3. The major water course joins the mill stream again just after the blockage and as the two water courses are only about 40 metres apart, sampling was done from the bridge over the major water course. This also allowed the sampling point at Venn Mill to be identical to the release point of the tracer to be sampled at Marcham.

There appears to be a misprint in table 4 of the Tender Document, as the Ordnance Survey map Landranger 164 shows the reach to have a length of 3.7 km rather than the 4.76 km stated in the table.

It was noticed that the water level on the 16th of April was no higher than the level on the 11th of March.

3.3 Marcham

The tracer to be sampled at Marcham was added at the same spot as sampling took place at Venn Mill, where it flowed along the Childrey Brook towards Mill Road, Marcham. It was sampled at the bridge, grid reference SU457 953. The travel distance given in table 4 of the Tender Document is stated to be 2.20 km but appears from the Ordnance Survey map Landranger 164 to have a length of nearer 3.1 km.

Initially we planned to send the tracer from the mill itself. However two attempts were unsuccessful as the tracer never appeared at Marcham, and by walking along all the reach a blockage found in the garden of the Venn Mill House, see also section 3.2. This blockage allowed only a very small amount of water to pass at a time and the large delay time plus the large amount of water coming from the water course led round Venn Mill implied a huge and unpredictable dilution. Therefore, in the successful study, tracer was added from the bridge wall into water that leads past the Mill, see figure 3.

Figure 4 illustrates the water ways near Marcham Mill (source NRA).

3.4 Abingdon

Childrey Brook joins to the River Ock just east of Marcham Mill. The tracer to be measured in Abingdon was, as arranged with the NRA, added in that confluence, grid reference SU458 953. There is an overflow facility between Sandford Brook and River Ock behind the brewery in Abingdon. There was hardly any overflow on the 3rd of

March, but an overflow of 8 to 10 cm in height was noticed on the 15th of April. No cross flow was noticed at the flow control arrangement near to the Tesco car park on any of the surveying days. The sampling point was midstream of the River Ock at the Old Iron Bridge at the confluence to River Thames, grid reference SU496 967.

4 Results of the Time of Travel Study

River water was successfully sampled and analysed continuously for Rhodamine WT at all four measuring points. In the associated figures the presence of Rhodamine WT is shown as a voltage deflection on the spectro fluorimeter against time in minutes after the tracer was injected. The cut-off time is the time corresponding to 10% of the Rhodamine WT peak concentration. The deflection given by a known standard solution is also shown, so that the actual concentration figure can be estimated by comparison.

Figure 5 to 9 show the results gathered during average flow conditions while figure 10 to 13 show the result gathered during high flow conditions. As there was a power cut to the data logger the deflection of a standard solution is not shown in figure 8 but in figure 9 from the back-up chart recorder. Here the 40 ppb standard solution gave a deflection of 9.4 on the chart paper scale. The cut-off time for the reach Marcham to confluence to River Thames was also estimated from this chart.

The data for 'first arrival time', 'peak arrival time' and 'average travel time' for each plume to pass the individual reaches is shown in table 1. The 'cut-off time' is also shown. This is defined as the time corresponding to 10% of the peak concentration. This data is used in the calculation of the 'average travel time'. The latter is defined as the time when the half of the dye has past a reach (or the time corresponding to the half of the area below the distribution curve). The area below the curve is calculated using 'first arrival time' and 'cut-off time' as time limits, and the 'average travel time' can then be found as the time corresponding to the half of the area. These calculations can be found on the floppy disk together with the raw data.

Two values are given for the 'first arrival time' of the reach Venn Mill to Marcham on the 16th of April. This is due to a small increase of the deflection after 197 minutes. After a little while the deflection was again back to background and did not rise until 209 minutes after the tracer was injected.

It is noticeable that the time of travel from East Hanney to Venn Mill was shorter during the average flow period than during high flow. As the water level at Venn Mill was approximately similar on the two surveying days, the times of travel were also expected to be similar. The longer travel time during high flow conditions could be due to delay somewhere on the reach caused by an object (e.g. part of a tree, a trolley etc.) 'fallen' into the river after the first study was carried out.

Table 1 also shows the flow measurements for the River Ock at Abingdon on the dates of the survey. These data are supplied by the RNA. Further more, table 1 shows the quantity of a 20% Rhodamine WT solution (i.e. 200g Rhodamine WT per litre solution) used for each reach. The amount in millilitre was added to a 10 litre container and mixed with water before injection to the river.

Reach	Date Flow conditions	Mean discharge at Abingdon (cumecs)	First arrival time (minutes)	Peak arrival time (minutes)	Average travel time (minutes)	Cut-off time (minutes)	20% Rhodamine WT consumption (ml)
Wantage STW to East Hanney	04/03/93 Average	1.320	67	79	81	103	35
East Hanney to Venn Mill	11/03/93 Average	1.290	199	227	229	265	150
Venn Mill to Marcham	11/03/93 Average	1.290	225	262	266	308	130
Marcham to River Thames,Abingdon	03/03/93 Average	1.390	379	449	452	536	200
Wantage STW to East Hanney	15/04/93 High	2.220	58	71	73	95	60
East Hanney to Venn Mill	16/04/93 High	1.960	203	235	238	272	180
Venn Mill to Marcham	16/04/93 High	1.960	197? 209?	245	247	283	180
Marcham to River Thames,Abingdon	15/04/93 High	2.220	244	318	315	380	400

Table 1 *The data for 'first arrival time', 'peak arrival time' and 'average travel time' for a plume to pass the individual reaches during average and high flow conditions.*

5 Conclusion

The principal results from time of travel studies at average and high flows in the River Ock are summarised in Table 1. There was about a 30% reduction in travel time for the Marcham to Abingdon reach at high flow in comparison to average flow. The reduction in travel time at high flow for the upstream reaches was only about 6 to 11%, and one reach showed a small increase in travel time.

The different response to the weather conditions in the upstream reaches compared to the Marcham to Abingdon reach is mainly explained by the difference in geology. A greater infiltration of rainwater in the upstream chalk areas decrease the quantity of run-off from the catchment that feeds the Letcombe Brook, in comparison to the quantity of run-off from the clay catchments of the other tributaries.

The increased time of travel from East Hanney to Venn Mill at normally high flow may perhaps have been due to water backed up by a local blockage somewhere on the reach, but there is no confirmatory evidence.

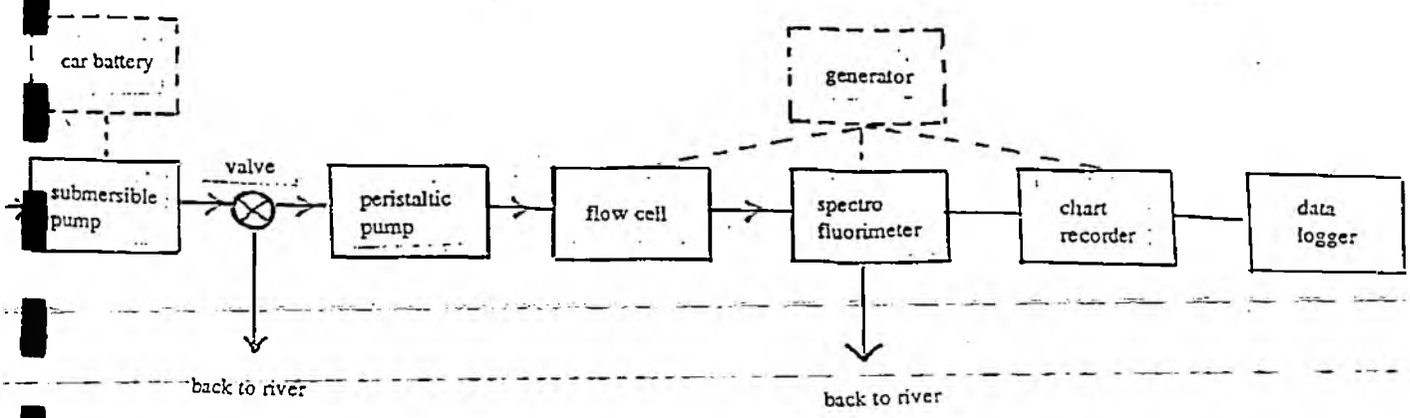


Figure 1 *Instrumental system for on-line analysis of Rhodamine WT concentration.*

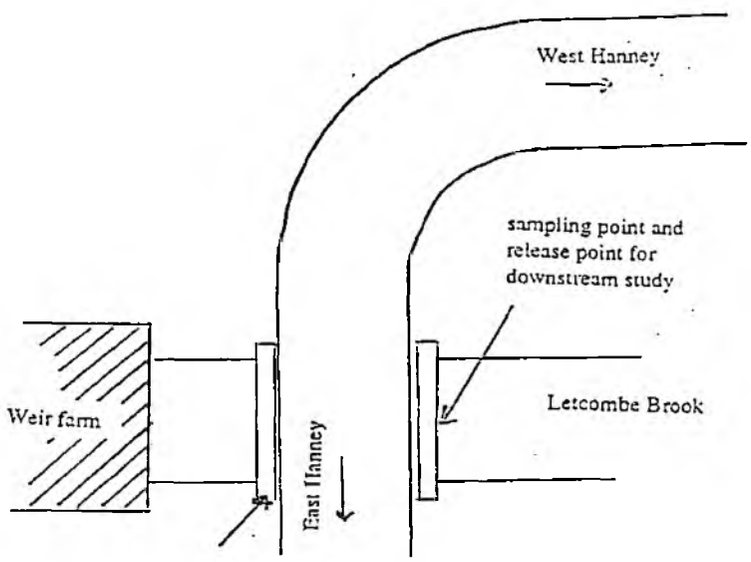


Figure 2 *Sampling and release point at East Hanney.*

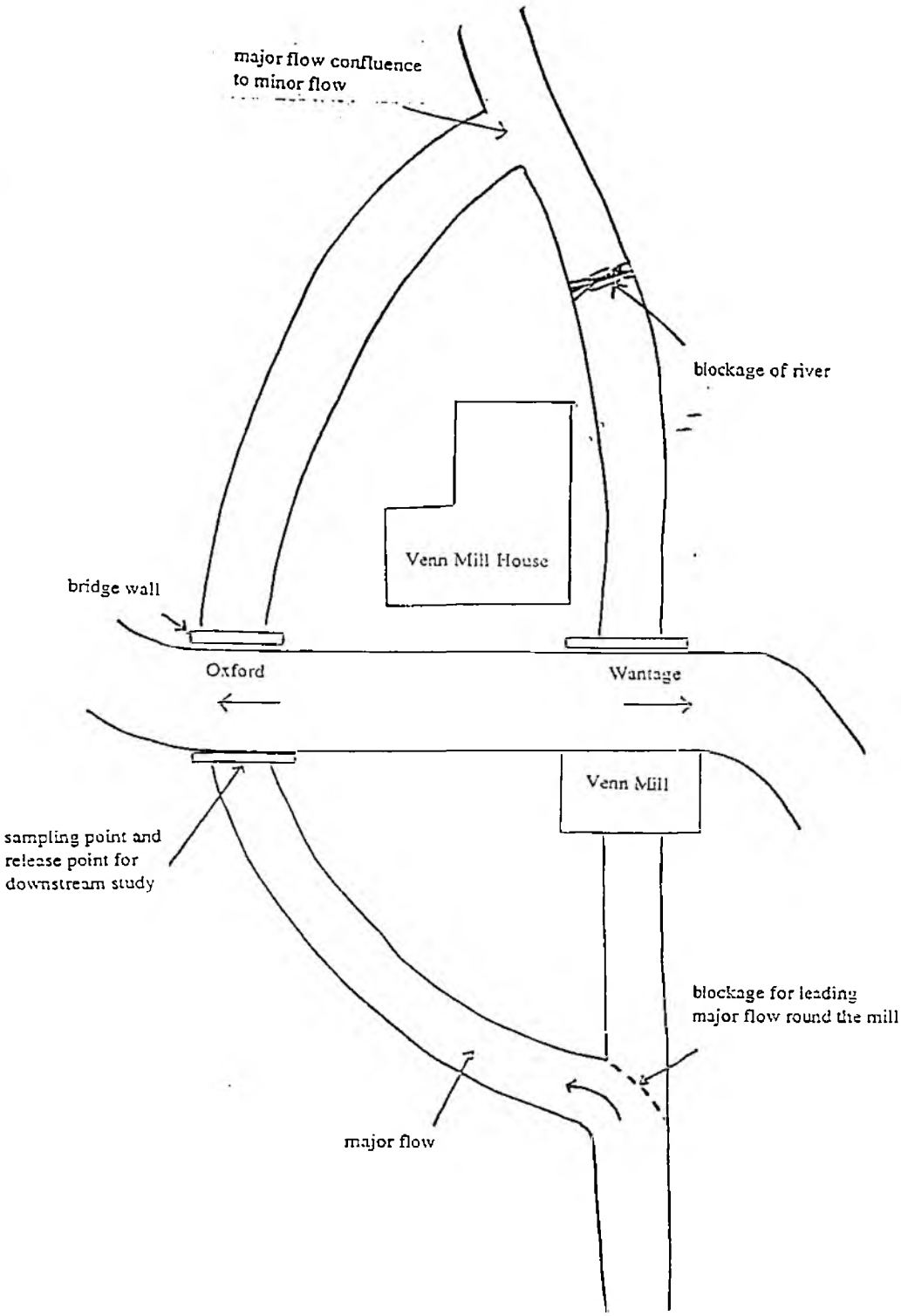


Figure 3 *Sampling and release point at Venn Mill and flow conditions.*

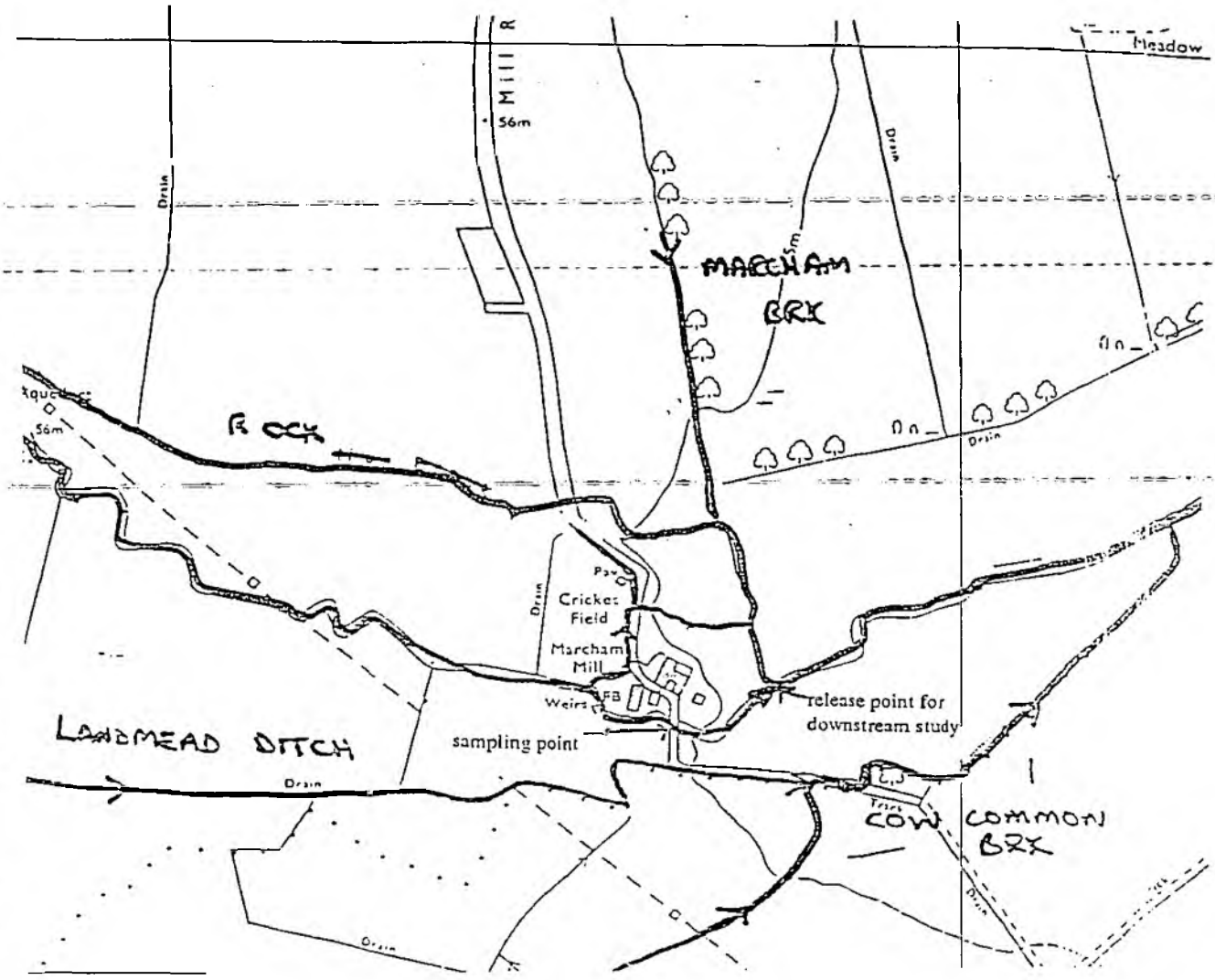


Figure 4 *The water ways near Marcham Mill. The sampling point was at the bridge , while the tracer was added at the confluence of the Childrey Brook to the River Ock.*

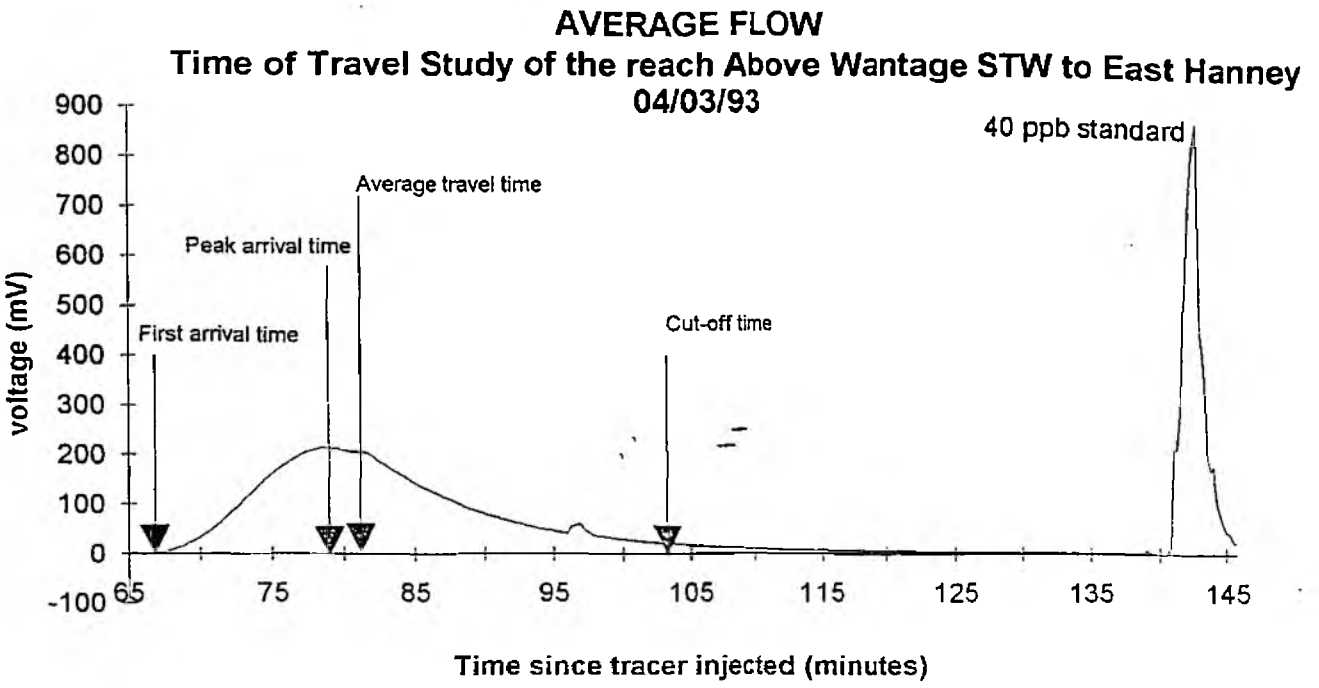


Figure 5 *Average flow: Time of travel study of the reach Above Wantage STW to East Hanney. The distribution curve for the Rhodamine WT is shown with a 40 ppb standard solution allowing the actual Rhodamine WT concentration in the river to be estimated.*

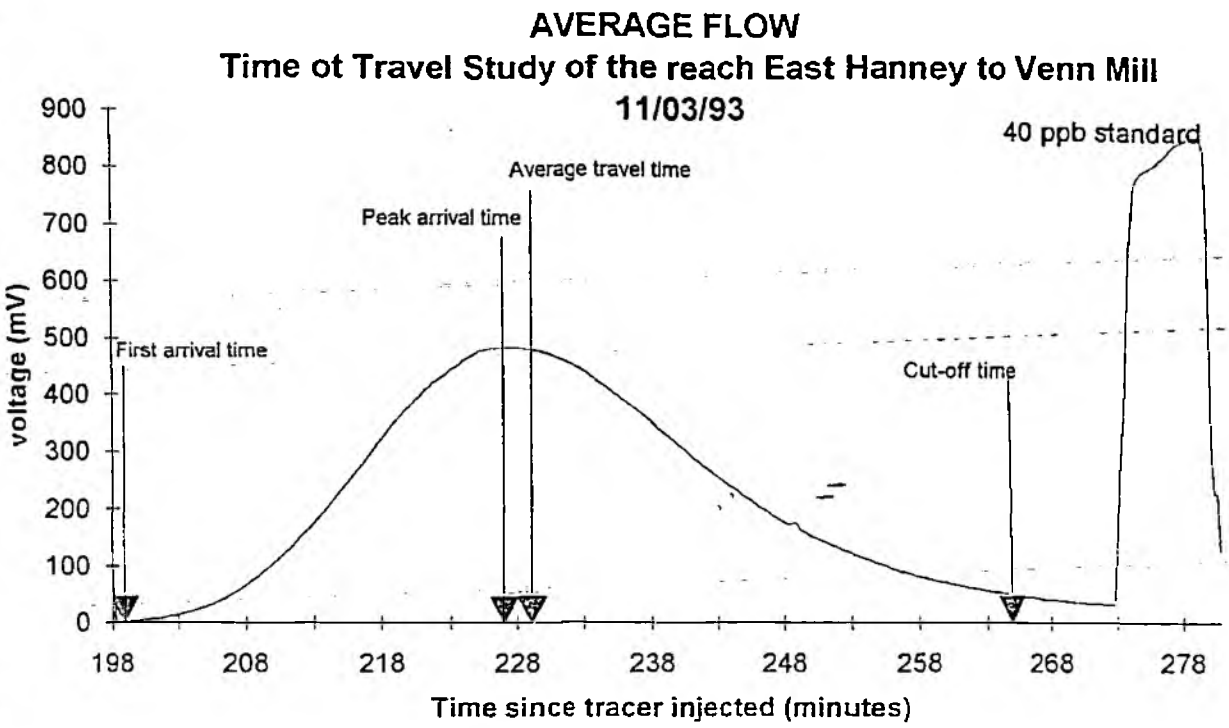


Figure 6 *Average flow: Time of travel study of the reach East Hanney to Venn Mill. The distribution curve for the Rhodamine WT is shown with a 40 ppb standard solution allowing the actual Rhodamine WT concentration in the river to be estimated.*

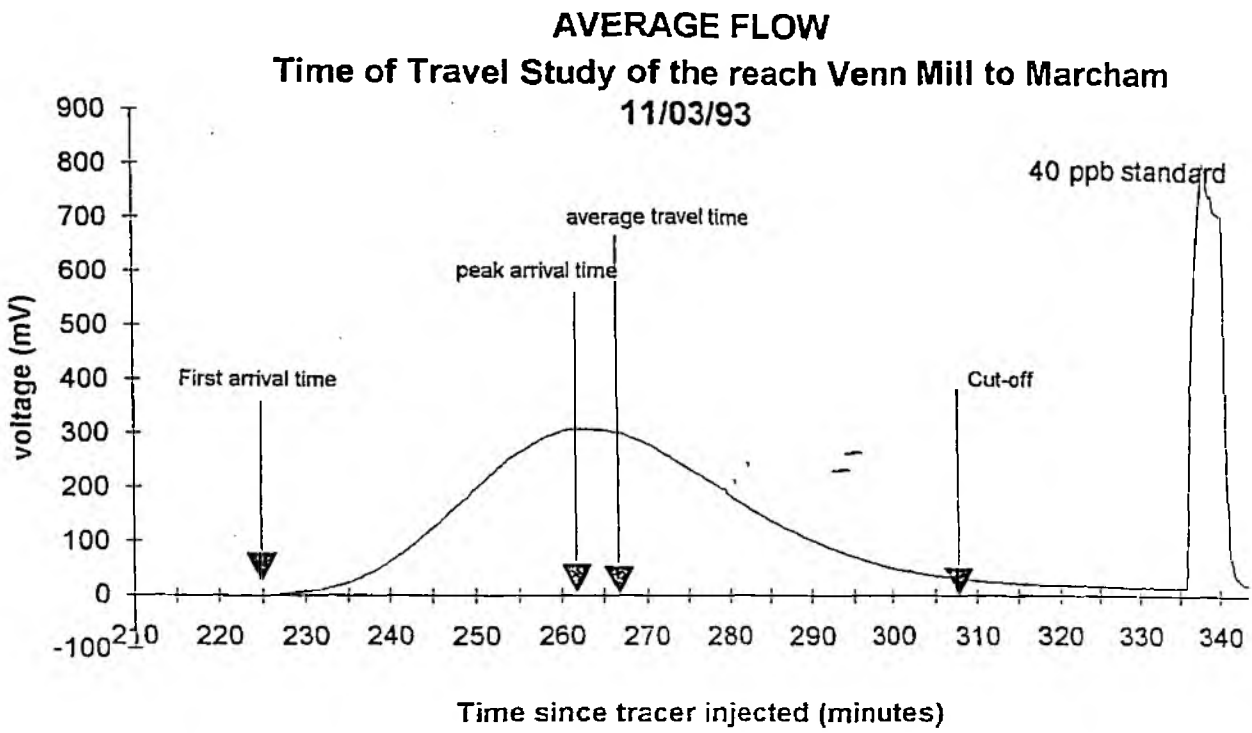


Figure 7 *Average flow: Time of travel study of the reach Venn Mill to Marcham. The distribution curve for the Rhodamine WT is shown with a 40 ppb standard solution allowing the actual Rhodamine WT concentration in the river to be estimated.*

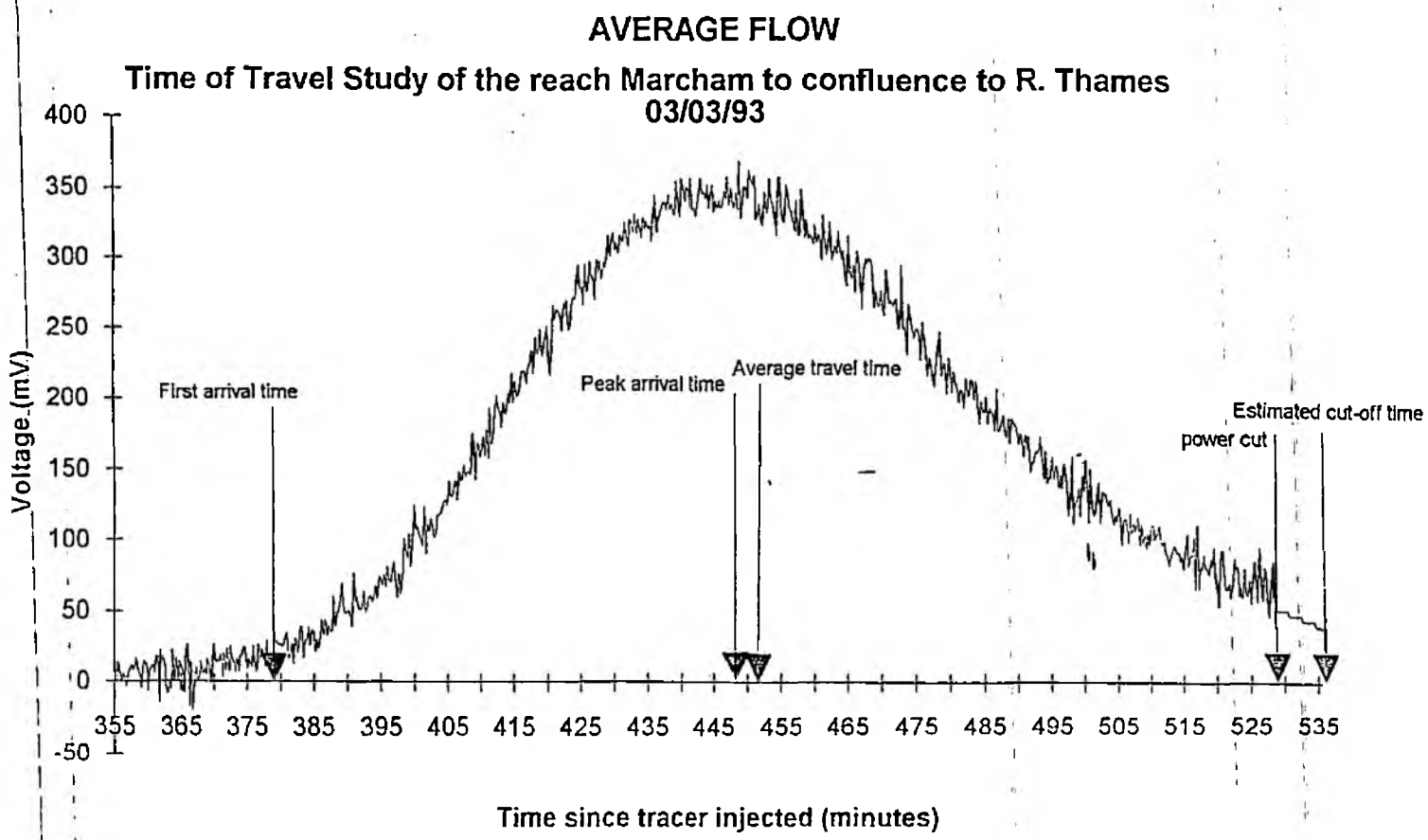


Figure 8 *Average flow: Time of travel study of the reach Marcham to confluence to River Thames, Abingdon, The distribution curve for the Rhodamine WT is shown.*

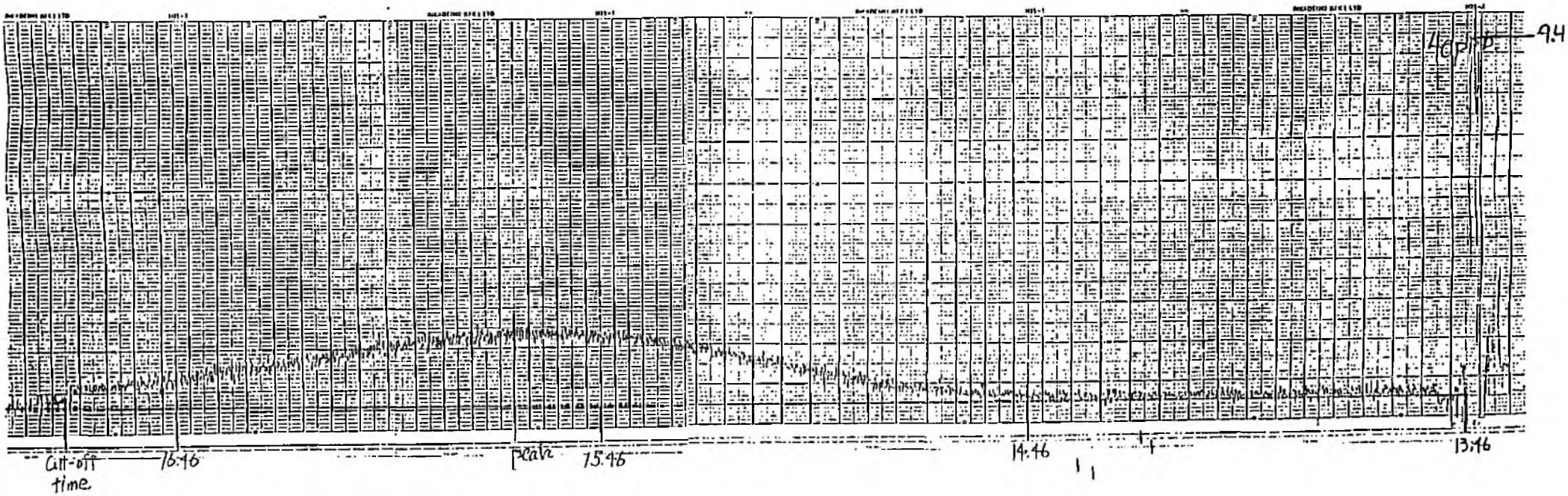


Figure 9 *Average flow: Time of travel study of the reach Marcham to confluence to River Thames, Abingdon. The distribution curve for the Rhodamine WT is shown with a 40 ppb standard solution allowing the actual Rhodamine WT concentration in the river to be estimated.*

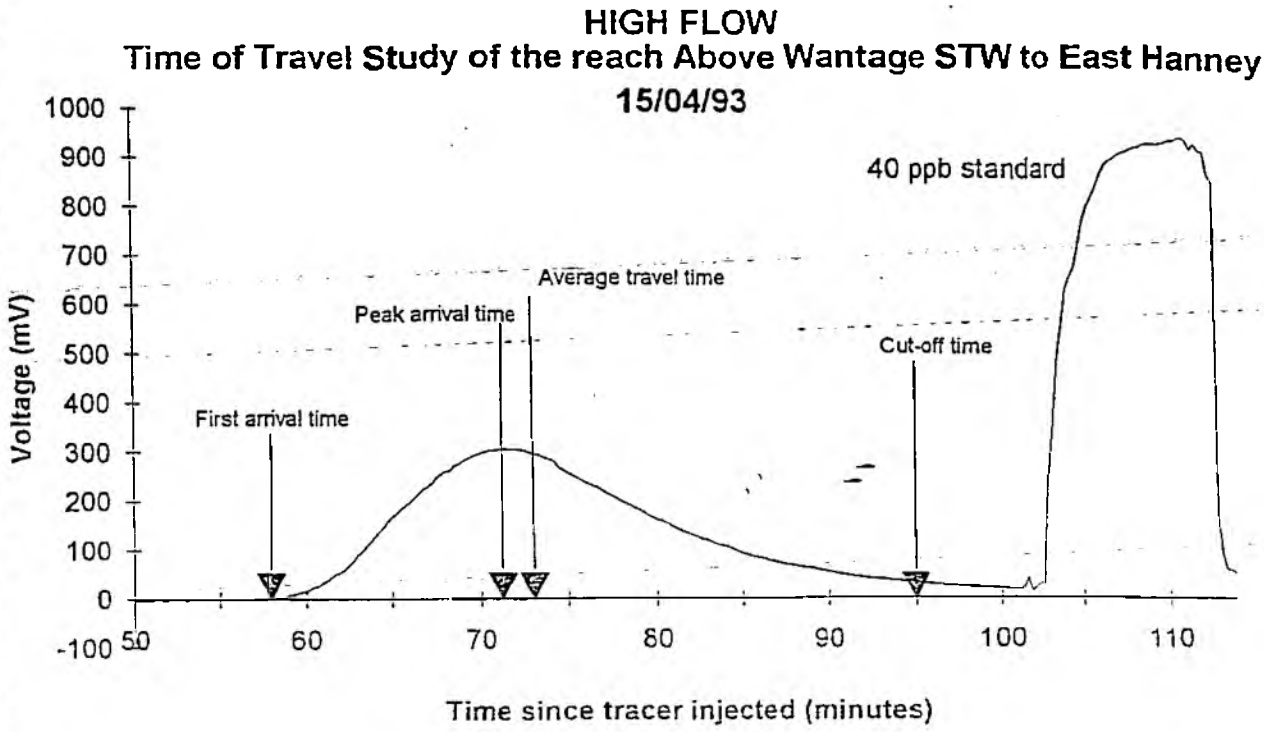


Figure 10 *High flow: Time of travel study of the reach Above Wantage STW to East Hanney. The distribution curve for the Rhodamine WT is shown with a 40ppb standard solution allowing the actual Rhodamine WT concentration in the river to be estimated.*

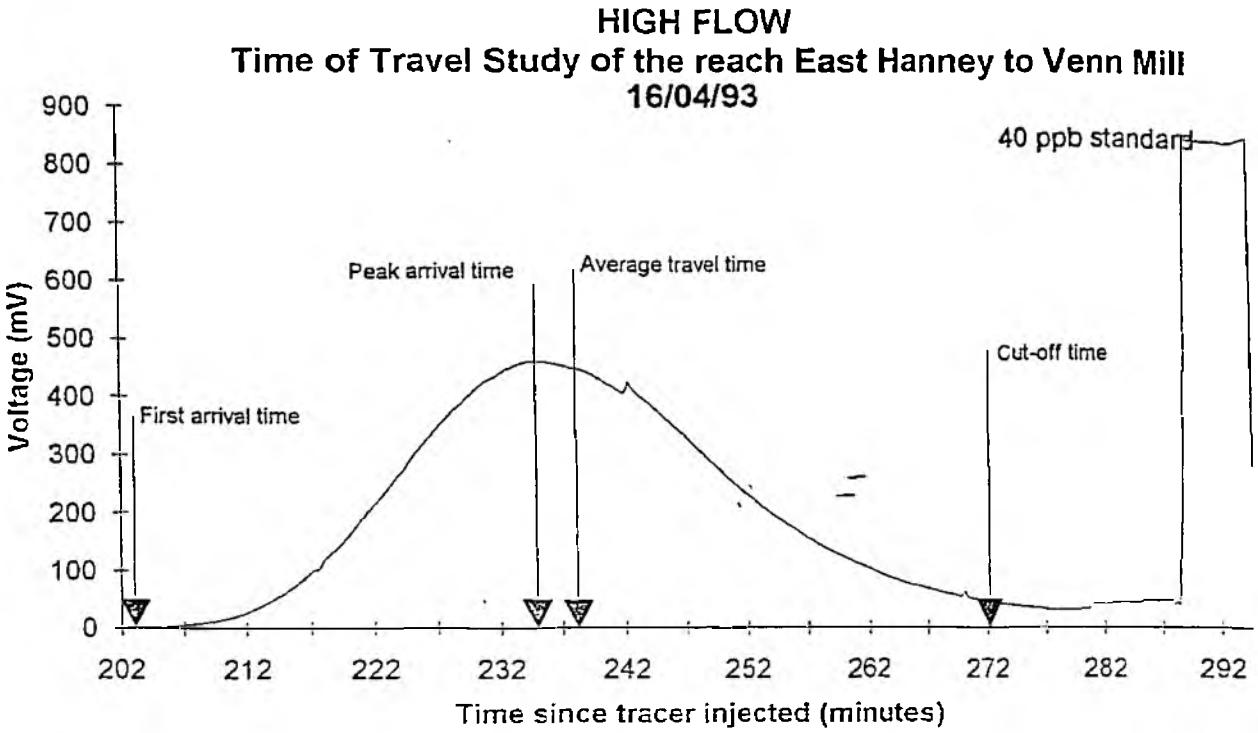


Figure 11 *High flow: Time of travel study of the reach East Hanney to Venn Mill. The distribution curve for the Rhodamine WT is shown with a 40ppb standard solution allowing the actual Rhodamine WT concentration in the river to be estimated.*

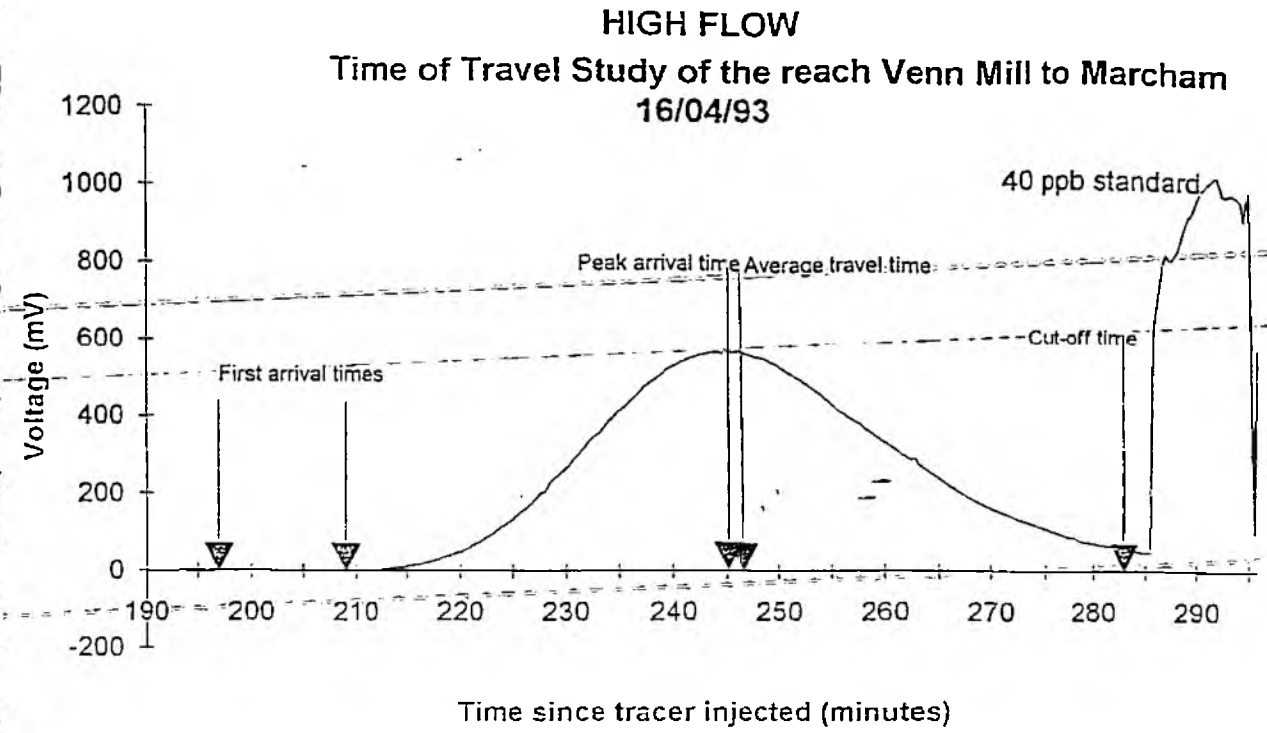


Figure 12 *High flow: Time of travel study of the reach Venn Mill to Marcham. The distribution curve for the Rhodamine WT is shown with a 40ppb standard solution allowing the actual Rhodamine WT concentration in the river to be estimated. There is a question about the actual 'first arrival time'.*

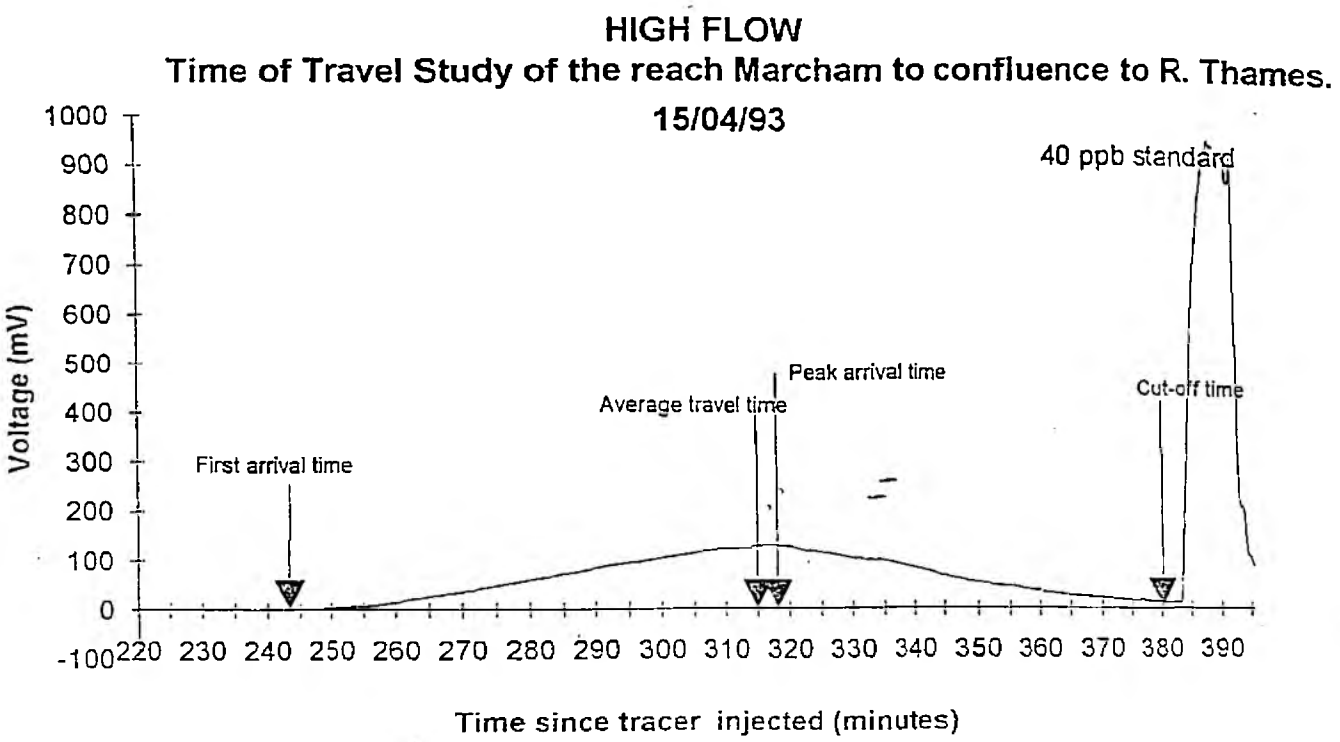


Figure 13 *High flow: Time of travel study of the reach Marcham to confluence to River Thames, Abingdon, The distribution curve for the Rhodamine WT is shown with a 40 ppb standard solution allowing the actual Rhodamine WT concentration in the river to be estimated.*