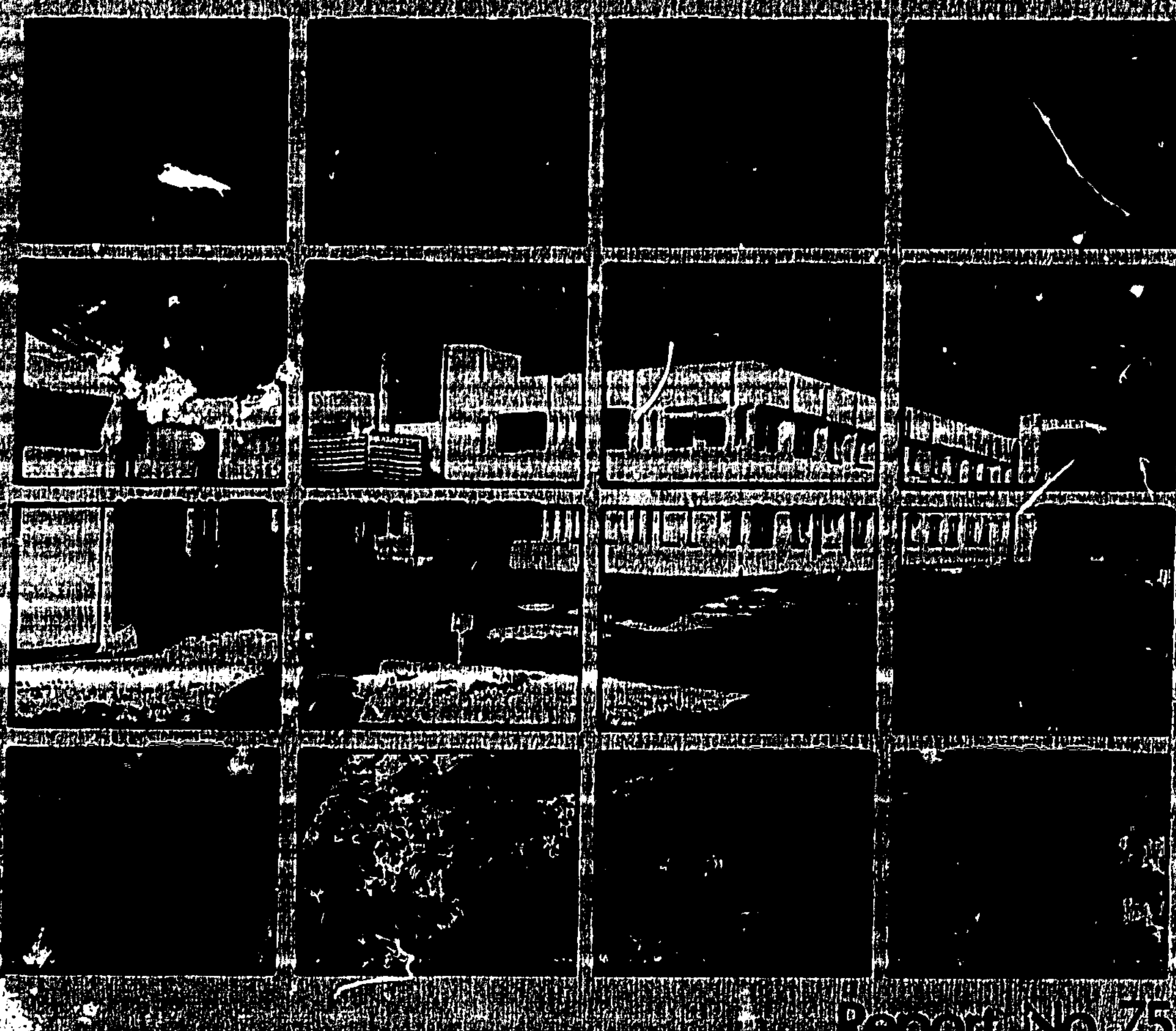
INSTITUTE of HYDROLOGY

Automatic dilution gauging in storm sewers



Report No 75

INSTITUTE
OF
HYDROLOGY

AUTOMATIC DILUTION GAUGING IN STORM SEWERS

by

R A HARVEY, C H R KIDD
and M J LOWING

ABSTRACT

Flow measurement in sewers is often based on measurement of water level with conversion to discharge using assumed values of roughness coefficient and empirical formulae. This is adequate for operational purposes but when research data are needed, the theoretical relationship must be confirmed by actual measurements. Dilution gauging techniques are available for such measurement but normally require operator attendance. High flows in storm sewers are short-lived and not easily created artificially; they can only be gauged by the dilution method if the operation is automatically triggered by rising water level. Suitable equipment is available but has not previously been assembled for the specific purpose of estimating instantaneous flows at short time intervals. A prototype apparatus has been developed at the Institute, installed in storm sewers at Stevenage and Bracknell, and found to be mechanically and electrically feasible. Gauging results are, however, mixed. Comparison with theoretical and flume-measured flows at the two sites has highlighted various practical problems which lead to pessimistic conclusions regarding the viability of automatic dilution gauging as a routine approach to stage-discharge calibration of high flows in storm sewers.

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1. INTRODUCTION

The accurate measurement of discharge from a sewered catchment is best achieved by a conventional flume or weir at the outfall. But, even when the outfall is not too far from the point of interest, the construction of a gauging structure is often impracticable and always expensive. However, research engineers frequently need to measure discharge within the existing pipe or culvert system. As it is rarely feasible to construct a suitable in-pipe control structure (unless this is done during the original laying of the sewer), the usual approach is simply to measure water level in an accessible section and to assume a unique relationship between that level and the discharge. The relationship is usually based on traditional formulae but these require pipe slope data and the estimation of roughness coefficients. Slopes may change at the point of measurement and roughness estimates can be rather subjective. In recent years engineers have returned to direct methods of flow measurement but with the aim of calibrating the stage-discharge relationship rather than providing a continuous record

Dilution gauging is a well established technique of flow measurement (B.S.I., 1964; W.R.A., 1970) and has been used for stage-discharge calibration of sewers (Blakey, 1969). The usual method, however, requires the manual addition of tracer to the flow followed by manual sampling at a downstream site. In foul sewers it is possible to predict when any particular discharge will occur and manual methods are satisfactory. In combined and separate storm sewers it is unlikely that a gauging team can arrange to be in position when large flows occur as such flows are due to rainfall and rise within minutes rather than hours.

It is rarely possible to introduce sufficiently large artificial flows to achieve a useful calibration so that there is obviously a need for a fully automatic dilution gauging apparatus to come into operation whenever natural discharges of any predetermined magnitude are exceeded.

Such systems have been developed elsewhere (notably, in this country, by Tucker 1974, 1975) but a fully automatic and portable package designed specifically for calibration of the stage-discharge relationship is not yet commercially or otherwise available. This report describes the development and testing of a prototype apparatus by the Institute of Hydrology for the Hydraulics Research Station under contract No. EM/3/75.

2. DILUTION GAUGING METHOD IN STORM SEWERS

The theory of the dilution gauging technique is well known. In the constant rate injection method, tracer solution is introduced at a constant rate into the river. If C_1 is the concentration of tracer injected at the rate q, C_2 is the concentration of tracer sampled from pipe flow Q and C_o is the background concentration of tracer, then, if the flow is constant (steady state) long enough for the equilibrium to be reached (time to 'plateau') and mixing is thorough, conservation of mass gives:

$$Q = \frac{C_1 q}{(C_2 - C_o)}$$

Injection can also take the form of a pulse, with sampling timed to encompass the passage of the pulse at the downstream site. This method, used by Tucker (1974, 1975), will give an average value of Q during the sampling period which may typically be five minutes. Because storm sewer flows are rarely constant the continuous injection technique with 'grab' or instantaneous sampling at regular intervals is more appropriate for the required purpose of relating specific measurements of level and discharge.

The above equation is valid only in steady state conditions, so a correction must be made for changing flows.

Gilman (1975, 1977) has proposed a residence time model which may be used to derive formulae for the estimation of the errors in gauged flows through a given hydrograph. It relies on a knowledge of (i) residence time distribution, which may be determined from the response to an instaneous input of tracer, and (ii) the manner in which this distribution varies with discharge.

Price (1976) has proposed a diffusion model based on dispersion theory. The model uses Amein and Fang's implicit method (1970) to solve the St Venant equations for long waves in open channels in conjunction with the dispersion (or diffusion) equation. Like Gilman's method, the model may be used to produce estimates of the error in calculated discharge from the above equation. Both models rely on the change in flow rate being smooth and slowly-varying. The term 'slowly-varying' is a relative one, and the change in flow rate may be taken to be relative to the mean residence time (or the average travel time in the reach). The likely order of magnitude of the mean residence time for sewer gauging is of the order of 3 minutes as compared to one hour in river gauging; and thus much greater changes in flow-rate may be tolerated in the dilution gauging of storm sewers. Fortunately, large concentrations of tracer (or tracer-like elements) are unlikely to be present in the background flow. Sometimes a single measure of background concentration will suffice but it is better to sample throughout the injection period in case the background concentration varies markedly with discharge.

The thorough mixing of tracer with the pipe flow is not usually the problem in storm sewers that it is in rivers. The turbulent flow associated with pipe junctions can often provide very good mixing. The rule of thumb of a mixing length for a straight pipe of 100 times the diameter should not be difficult to satisfy.

3. INSTRUMENTATION

Two sets of prototype apparatus have been installed. The first was installed near the outfall of the Shephall catchment at Stevenage in 1977, and the second set at the outfall of the Wildridings catchment at Bracknell in 1978. The layout, shown in Figures 1 and 2, is common to both installations, and features:

i. Three samplers - Automatic Liquid Samplers Ltd

ii. Mariotte bottle

iii. Magnalatch valve and switching circuit

iv. Level measurement device

v. Recording device - Microdata logger.

FIGURE 1

Upstream instrumentation

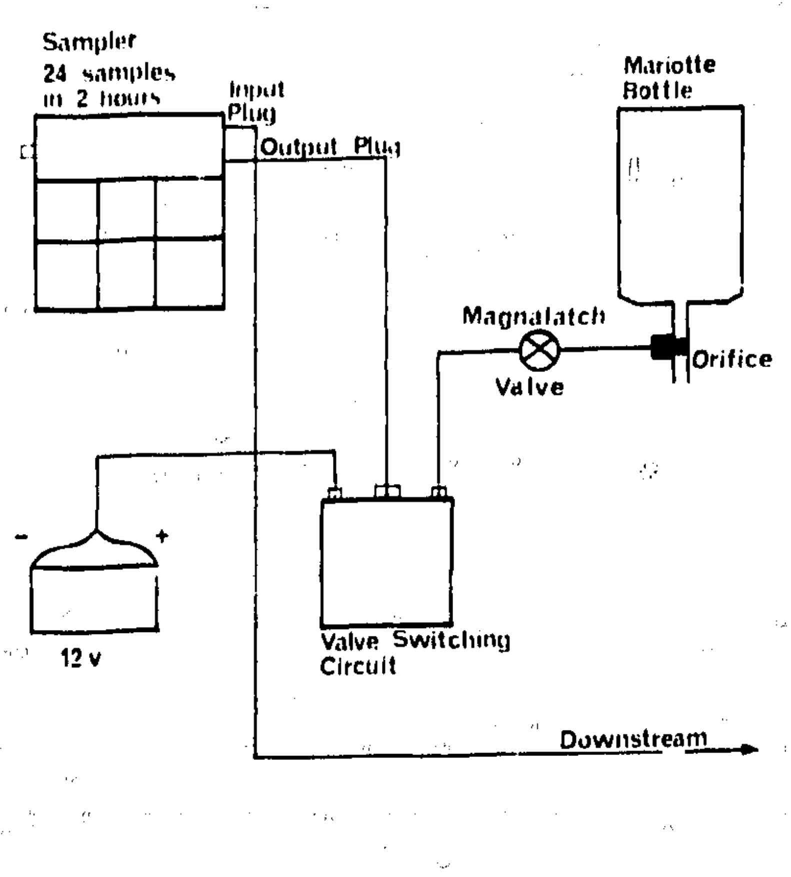


FIGURE 1: UPSTREAM INSTRUMENTATION

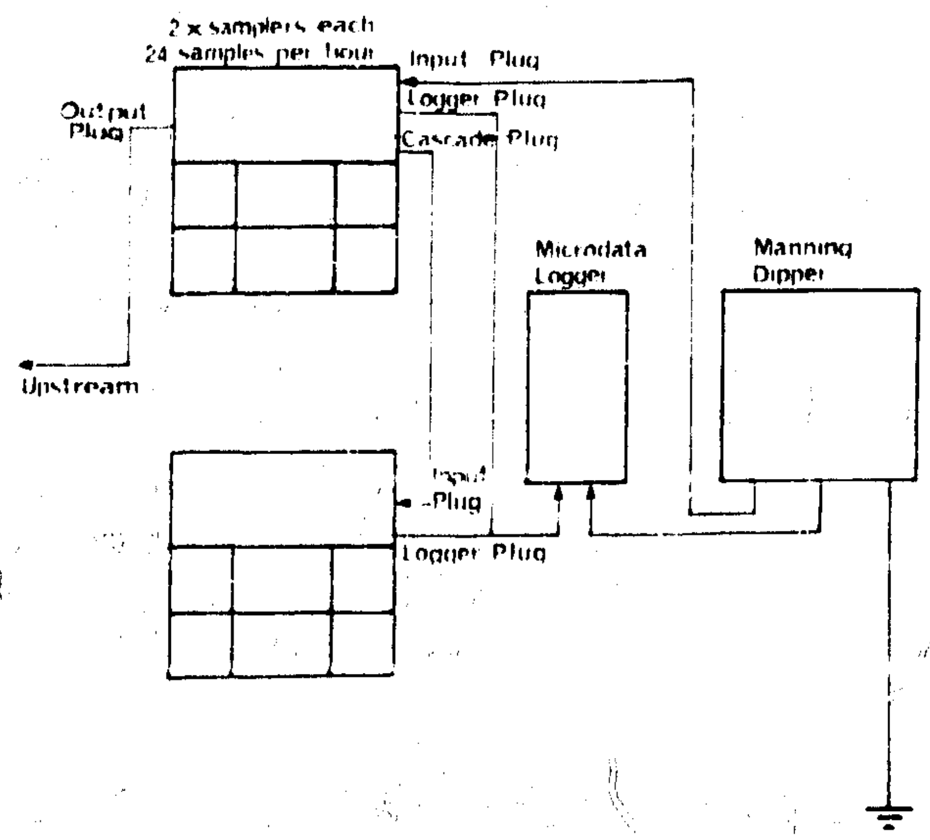


FIGURE 2. DOWNSTREAM INSTRUMENTATION

FIGURE 2

Downstream instrumentation

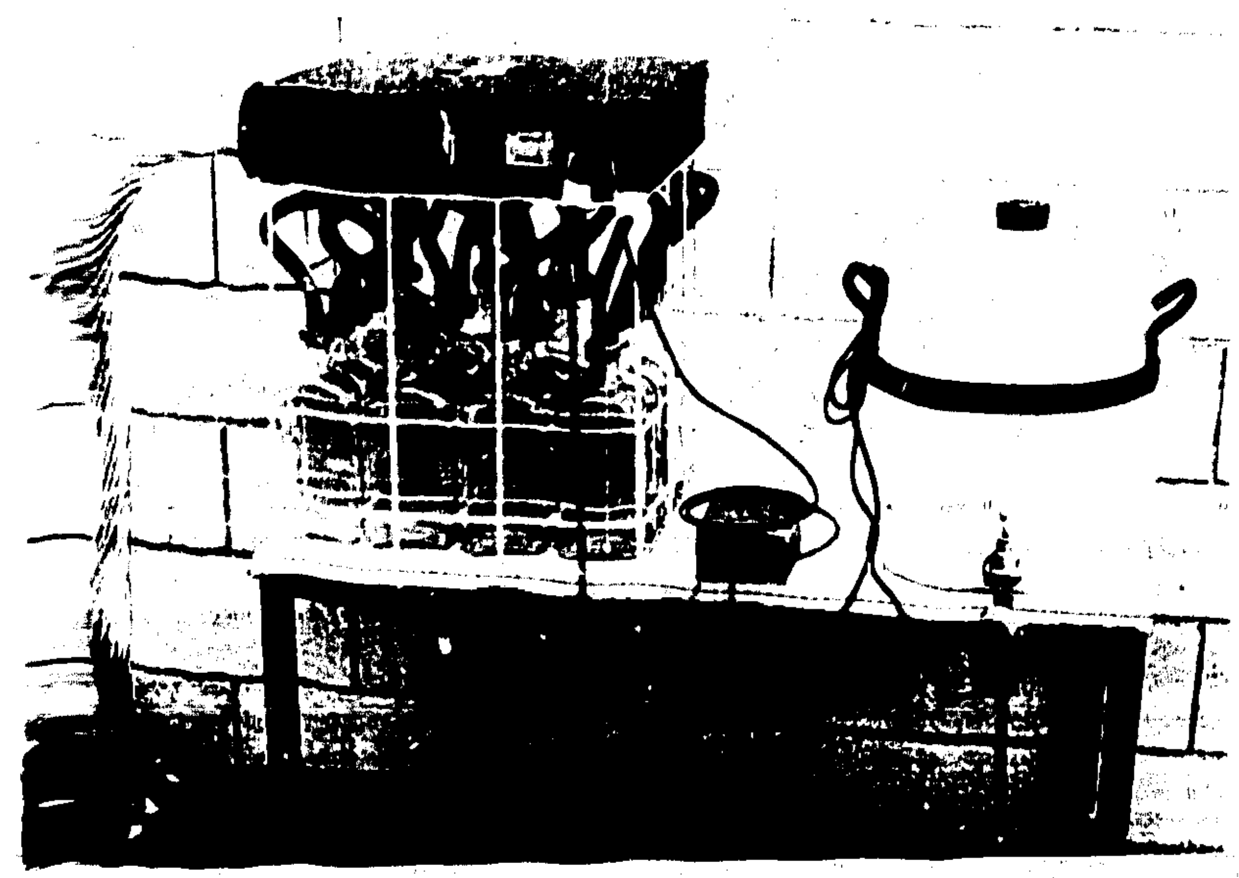
3.1 Samplers

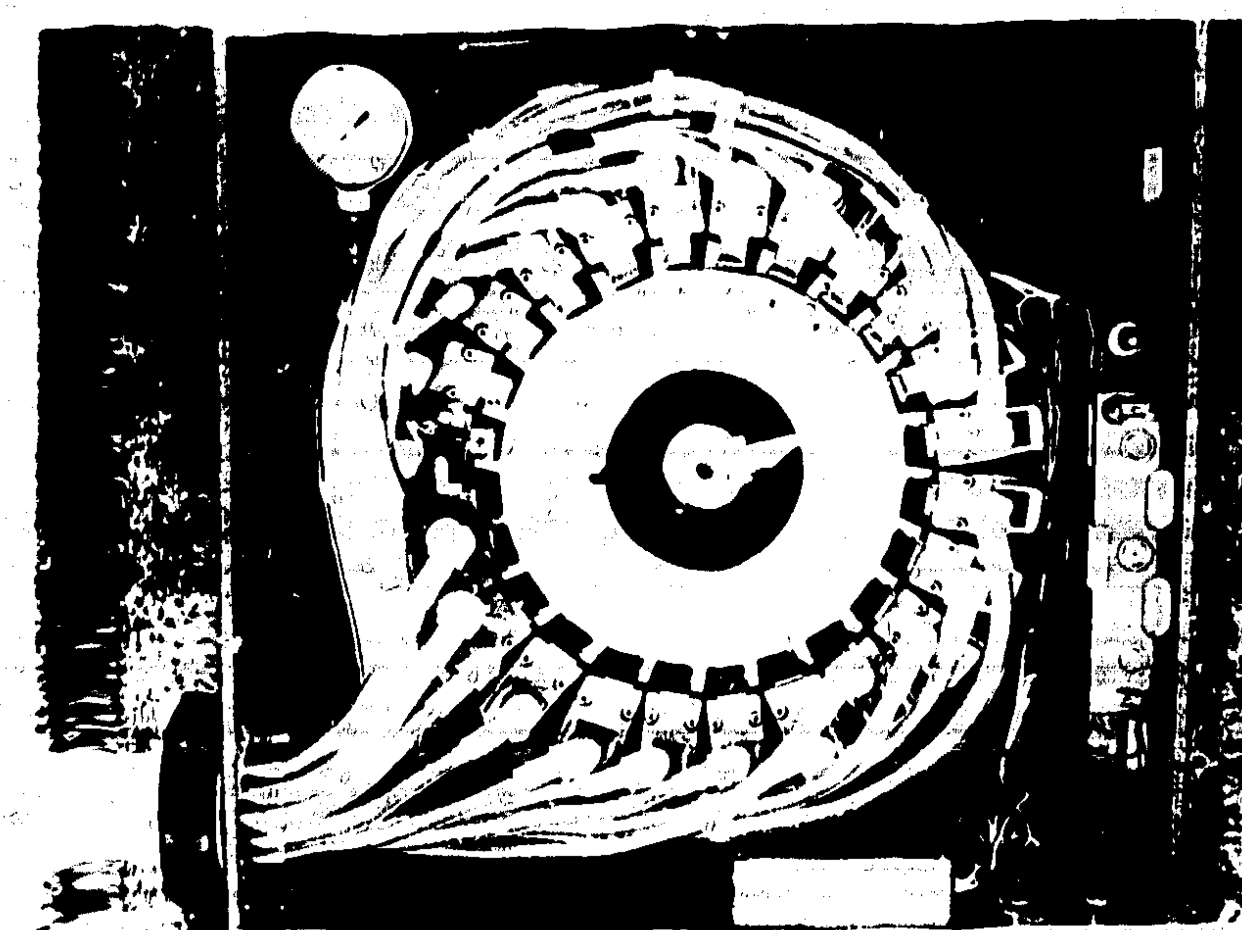
The samplers chosen were the Automatic Liquid Samplers Ltd. 4BE vacuum samplers with 24 bottles (Figures 3 & 4). This sampler has proved to be reliable in many applications. An important reason for its selection is that by using one of the clocks available a sampling interval of 2½ minutes could be obtained. This was considered desirable in the rapidly changing flow situation which occurs in many storm sewers. This could not be obtained by any other sampler that did not require mains power. (N.B. The upstream or background sampler is set to a five minute interval.) The sampler requires very little electrical power; the small, rechargeable batteries need only be replaced after three or four gaugings.

One disadvantage is the need for individual sampling lines which, when bundled together, represent a significant intrusion into the flow of water and at high velocities need to be anchored securely to ensure good sampling.

An important criterion in the design of the samplers was that all the samplers should be interchangeable as far as possible, and so with this in mind all the samplers include identical modifications. The samplers normally provide input and cascade plugs (DIN connections). Each sampler was modified to include two additional plugs, namely, the logger and output plugs. The different plugs perform the following functions.

INPUT PLUG: This plug is used for the remote operation of the sampler. Whenever there is a short circuit or closed switch across this plug and the switch inside the sampler is set to 'external',





the sampler can either 'hold' itself on regardless of the change in water level or stop-and-start depending on the water level.

CASCADE PLUG: This is a standard plug, which is connected to the input plug of a second sampler, and can be used to start the operation of the second sampler once the last sample has been taken from the first sampler. Hence any number of samplers can be chained together in this way.

LOGGER PLUG: This is a modification to the basic sampler and provides a two-volt signal between the 1st and 24th sample; this is sent to the Microdata logger and thus records the time of start and end of sampling. The signal is provided only when the sampler is in operation.

OUTPUT PLUG: This plug is also a modification to the original sampler and provides for operations to be performed in parallel with the sampler. This is done by providing a closed switch whenever the sampler is in operation. At the upstream site this is used for the injection of tracer whenever the sampler is operational. At the downstream site it is used to trigger the upstream sampler by connection to its input plug.

3.2 Mariotte bottle

The constant rate injection device is the Mariotte bottle. The method of operation of the Mariotte bottle can be seen in Figure 5. The Mariotte bottle is simple with no moving parts and there is little that can compete with its accuracy. Provided the orifice diameter, the head h, and the viscosity of the liquid do not vary, it will provide a constant and consistent flow rate. Because the apparatus is installed underground there is minimal temperature variation and viscosity changes are insignificant.

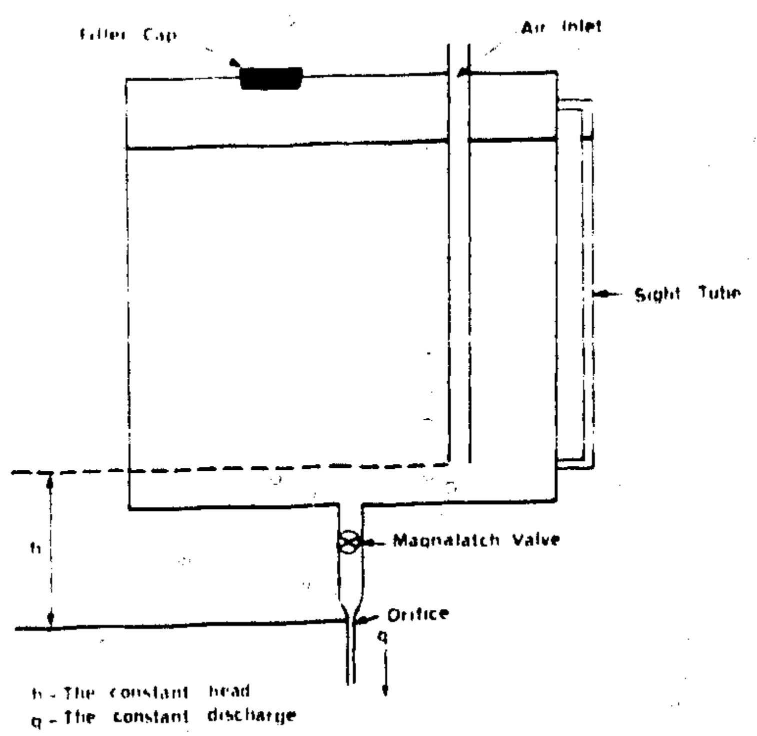


FIGURE 5

Mariotte bottle

FIGURE 5 MARIOTTE BOTTLE

The head, h, must be constant if the bottle is to reproduce a constant flow rate, so care must be taken that the Magnalatch valve added to the Mariotte bottle to control the flow does not move. If the valve or the orifice has to be shifted then the flow rate from the bottle should be re-established.

The bottle constructed was of a reduced capacity (only 15 litres) compared to the normal IH 50-litre bottle which is far too large to operate in the confined space of a manhole. The 15-litre bottle provides enough solution for a two-hour gauging, the duration of operation of two downstream samplers working in series.

To make the Mariotte bottle as 'standard' as possible, it was constructed with a sight tube. This was later found to be a mistake because the bottle is sufficiently transparent to check the level of the contents and the tube only made the bottle more fragile and prone to leaks.

The flow rate from the bottle can be checked by weighing a timed release. When this is done it is important that the discharge from the Mariotte bottle should have stablised. (The flow from the bottle is constant only when the bottle is bubbling - that is, when air is entering through the air inlet to replace the liquid released.)

3.3 Magnalatch valve

The valve originally chosen to switch on the injection of tracer from the Mariotte bottle was a simple solenoid valve. It proved to be most unsuitable however as it consumed a heavy current which heated the valve and the water, and a constant flow rate could not be maintained.

The Magnalatch valve draws no current between switching. A pulse on one input will open the valve and a pulse on a second input will close the valve. The valve is very economical on power, does not heat up and remains locked open unaffected by small changes in the power supply. The only disadvantage is the small amount of electronics required to provide the switching pulses. The circuit for the control of the valve is given in Appendix II.

3.4 Water level measurement

Some water level measurement device will be needed whenever dilution gauging calibration is carried out. In many cases, a suitable instrument will already exist. At Stevenage there is an air displacement (Arkon) gauge producing a graphical record. But there were some doubts concerning its accuracy and a Manning dipper - a water surface hunting device - was installed in parallel. This, too, posed problems but, between the two instruments, a consistent record of water level was achieved. Because the dipper is simply one of several alternative level measurement devices which are needed before and/or after the dilution gauging calibration is performed, it is not normally to be regarded as part of the apparatus. In the Stevenage system, however, it provides the trigger which activates the system. At Bracknell, the installation was immediately upstream of a standing-wave flume (constructed by Kent Instruments). Depth was already being measured in the existing stilling basin to which was added a float switch for triggering the dilution gauging apparatus.

3.5 Recording device - Microdata logger

The recording device is needed mainly to record water level, but a further advantage is that other information such as the triggering of the samples can be recorded with good synchronisation in time. This may not be essential in a final design when it may be possible to align stage and flow hydrographs by reference to their peaks and troughs. However, experience has shown that it is desirable to have independent assurance of relative timing.

The logger is manufactured by Microdata and stores data on cassette tapes. It records voltage levels on up to twelve channels at a predetermined scanning interval (one minute here). Only four channels are used in this application, water level being recorded on three channels (one 'coarse' potentiometer and two 'fine' ones) while the fourth records a two-volt signal (turned on by the opening of line 1 and turned off by the opening of line 24) to indicate the operating time of the sampler.

4. INSTRUMENT OPERATION

The dilution gauging equipment is activated by a closing switch at the downstream site. The closing switch is provided from within the dipper at Stevenage and by a float switch suspended into the stilling basin at Bracknell. At Stevenage the switch within the dipper is closed by a cam fixed to its coarse potentiometer. The completed circuit is connected to the input plug of the No. 1 downstream sampler.

The samplers can be operated in two modes. They can be operated so that once the level trigger has been shut and the samplers activated, then the gauging will continue regardless of any fall in flow (it will be 'held') or alternatively, the gauging can be switched so that it is only in operation when the level is above the triggering level ('normal'). There is a 'hold'/'normal' switch on the outside of the sampler for this purpose (Figure 3). Experience suggests that the first option is the more appropriate.

Once the sampler downstream has been activated, the output plug will provide a closed circuit, and since this is connected (via cable laid up the pipe) to the input plug of the sampler upstream, it too will start operation. Once the upstream sampler has started, its output plug will provide a short circuit and the Magnalatch valve switching circuit will open the valve on the Mariotte vessel for the injection

of tracer. In this way the instruments are chained so that all are operating together.

Whenever two samplers at the downstream site are in use, the cascade plug from the first sampler can be connected to the input plug of the second; when the first sampler has finished the second sampler then automatically commences operation. Alternatively, the two downstream samplers can be operated in parallel to provide a check on the mixing of the tracer.

Figure 6 is a view of the downstream installation at Bracknell. The samplers are mounted over the throat of the standing-wave flume, and the sampler tubes are brought back to a position on the walls 3 m upstream of the throat.

5. FIELD TRIALS

5.1 Results from 1976 experiments

During 1976, one set of apparatus was installed at Stevenage. Mechanical details of fixing brackets and shelving used for the installation of the equipment will vary from site to site and are omitted here except to stress the importance of anchoring the sampling tubes firmly to the walls and invert of the pipe. In any procedure involving highly accurate chemical analysis it is obviously important to observe meticulous standards of cleanliness and procedure in the field. Appendix IV details the procedure currently being used and has been subject to continual refinement in the light of experience. Laboratory analysis procedures are not described in this report but the success of the system as a whole depends on them. The Institute's Hydrochemistry Section supplied the necessary expertise and equipment.

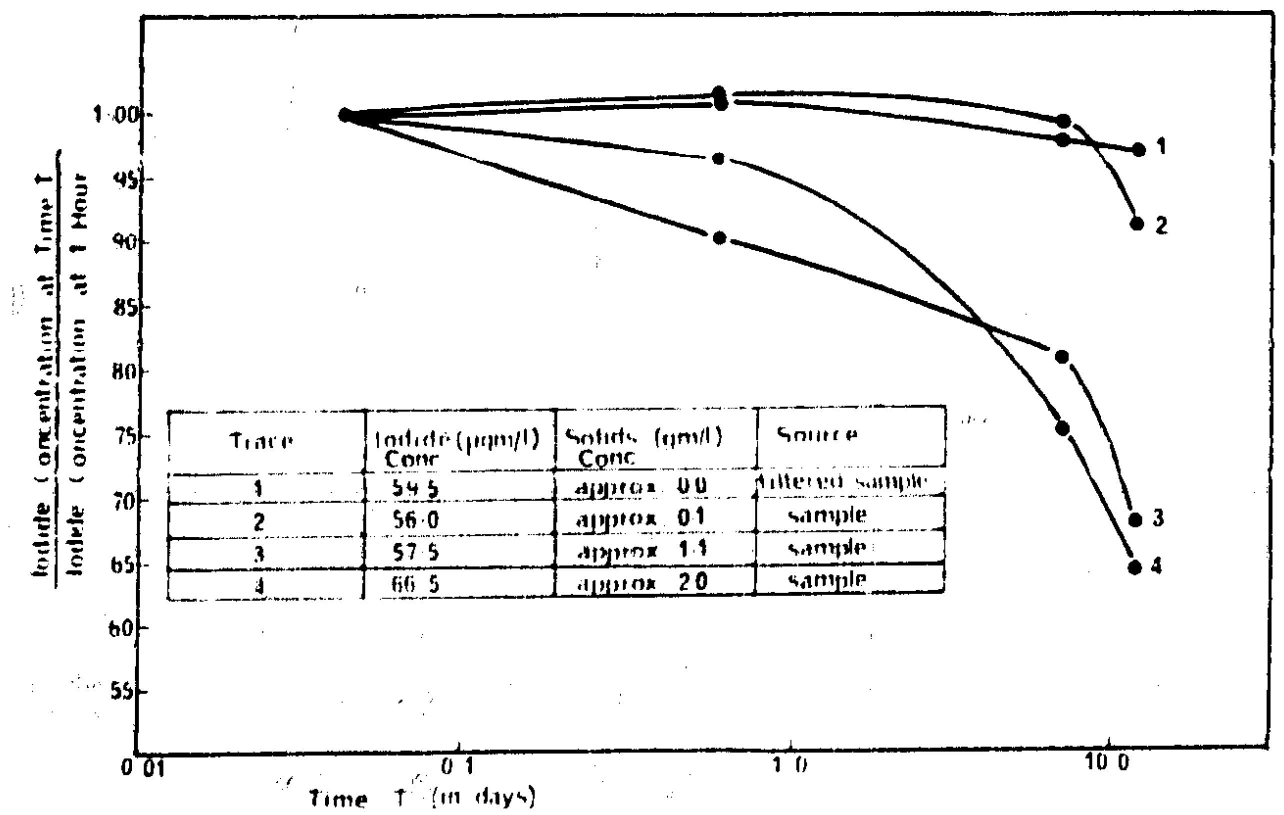
The Shephall catchment at Stevenage is a 162 ha catchment, 35% of which is considered to have an impervious surface. Water level is measured, by both the Arkon and dipper instruments, at the last manhole before the outfall to the Bragbury Brook. The two downstream samplers in series were also sited here. The injection of the sodium iodide solution as tracer took place at the next manhole, 137 m upstream.

The equipment was installed and began working in August 1976. The first two months of field trials were occupied by debugging the instruments and establishing field procedures. During November and December, however, five gaugings were achieved. The results are shown as Figures A5.1 to A5.5 in Appendix B. Each figure shows the observed water level taken from the Arkon recorder. Despite earlier concern it appears that the two depth recorders are in good agreement up to 250 mm (the five events are within this range. The stage hydrograph has been converted to theoretical discharge using the stage V discharge rating curve developed by Colyer (1976A) and, on each figure, the plotted points relate to dilution gauging results.

In two cases (Figures A5.2 & A5.5 in Appendix V) a correction has been made to the dilution gauged discharges based on the models proposed by Gilman (1976) and Price (1977). The estimated error was calculated from the theoretical discharge in both cases. Note the agreement in error prediction between the two models. From this point on, the Gilman model only has been used in estimation of the corrected discharge. In the 1977 and 1978 results, a correction has been made by the method described, but the error values are not shown. The results presented in the five figures are inconsistent but, on the whole, show fair agreement between the theoretical and dilution gauged flows. In one case (Figure A5.1), the dilution figures are marginally lower but in the others the theoretical discharge could be underestimated. There are such obvious errors in Figures A5.4 (the whole event) and A5.5 (the rising limb), however, that there is clearly a substantial problem. All the obviously erroneous results appear to be overestimates of the flow resulting from

uncharacteristically low tracer concentrations. This problem was identified as being associated with the adsorption of the iodide tracer on to particulate matter in the samples. The quantity of suspended matter varies greatly from one event to another and also during an event. The 'first flush' effect may explain why the results during the rising limb in storm A5.5 are erroneous while the falling limb seems more reasonable.

To investigate the adsorption phenomenon further, an adsorption test was carried out on a sample which contained a greater than usual quantity of suspended matter; The results of this test are shown in Figure 7.



Trace	Iodide (μgm/l) Conc	Solids (gm/l) Conc	Source
1	59.5	approx 0.0	filtered sample
2	56.0	approx 0.1	sample
3	57.5	approx 1.1	sample
4	66.5	approx 2.0	sample

FIGURE 7. ADSORPTION TEST

This test shows that there is appreciable adsorption of iodide on suspended matter in the typical samples containing relatively large solids concentrations. Some of the iodide fall-off occurring late in samples 1 and 2 could also be due to partial oxidation of the iodide, a reaction which can be aggravated by sunlight. These preliminary findings should not be interpreted as suggesting that adsorption of iodide is a universal problem for its use in dilution gauging. Neal and Truesdale (1976) have concluded that sorption of iodide on riverine sediments should not generally cause significant error in the dilution gauging of natural water courses. A 150 μ filter is being incorporated to reduce the quantity of suspended matter in the samples. This will not screen all the sediment and care must be taken to ensure that this filter does not result in cross-contamination between samples.

The chief conclusion from the 1976 experiments was that lithium chloride might be a more suitable tracer than sodium iodide for dilution gauging in storm sewers. A more rigorous examination of the tracer problem was therefore initiated.

5.2 Results from 1977 experiments

During 1977, the Stevenage experiment was continued as previously, but with the added feature of a standing wave flume sited at the outfall (some 100 m downstream of the dilution gauging site). This allowed greater confidence to be put on comparison between dilution gauged and observed flows.

A second set of apparatus was installed in the Wildridings catchment at Bracknell, where the downstream gauging site is just upstream of a standing wave flume and the injection point is 77 m upstream. The catchment is approximately 11 ha in area and thus has a shorter response time than the Stevenage catchment.

The question of tracer suitability was studied in detail by the Institute's Hydrochemistry Section but not as a part of the HRS contract. Reported by Neal and Jordan (1978), this work supports the preliminary findings mentioned in the previous section, and it was decided henceforth to use lithium chloride as a tracer.

Satisfactory gaugings were obtained for five events at Stevenage (Figures A5.6 to A5.10 in Appendix V) and for two events at Bracknell (Figures A5.11 and A5.12). The reliability of the instrumentation was slightly worse than the previous year. In each case, the dilution gauging estimates have been compared with flume-measured discharges. A number of conclusions may be drawn from the results:

(a) In the majority of cases, the dilution gauging results produce a consistent profile which matches the profile of the observed hydrograph. The absolute values are in error, and the residuals tend to be a constant proportion of the measured discharge at all points during an event. This suggests either an incorrect estimate of the tracer injection rate (which directly affects the estimated discharge) or contamination of the downstream samples in a systematic manner.

(b) The injection rate is estimated by taking a 5-minute sample of injected tracer when the Mariotte bottle is full. This proved satisfactory when sodium iodide was used as tracer and also under laboratory conditions using water. However, there is now evidence to suggest that the column of lithium chloride solution has a chemical effect either on the brass nozzle assembly of the Mariotte bottle or on the inside of the Magnalatch valve. The observed injection rate has varied through the experimental period for the Stevenage system (a similar phenomenon has been observed at Bracknell) and has tended to decrease with time.

(c) Due to the fact that adsorption manifests itself in a random fashion from sample to sample, the results suggest that the adsorption problems associated with the use of sodium iodide in 1976 appear to have been eradicated by the change to lithium chloride.

(d) Results from Bracknell demonstrate that the choice of distance between dosing and sampling can be delicate. Errors due to gauging in varying flow vary linearly with the product of the mean residence time in the reach and the decay rate of the recession (or the growth rate of the rising limb). In the case of the Stevenage experiment, the catchment is approximately 150 ha and the decay rate is such that errors due to gauging in varying flow are not high. In Bracknell, on the other hand, the catchment is about 10 ha and relatively high decay rates result in considerably higher errors despite the fact that the gauging reach is shorter (77 m rather than 137 m). In the Bracknell case, these errors are about as high as might be tolerable for acceptable accuracy of measurement, and yet the mixing length is minimal. In catchments of the size of Bracknell, it will prove necessary to pay careful attention to the length of gauging reach to ensure a satisfactory trade-off between mixing and accuracy.

The 1977 experiments demonstrated two main areas for urgent attention. Firstly, the mixing of the tracer needed to be examined by putting the two downstream samplers in parallel. Secondly, the field procedures with particular respect to the estimation of the injection rate and the possibility of contamination in the sampling tubes, needed to be examined in greater detail.

5.3 Results from 1978 experiments

Dilution gauging continued at the two sites during 1978. The main feature of the year's programme was the marked reduction in reliability of the apparatus. The sets of instrumentation contain so many inter-dependent components that a considerable loss of data might have been expected (breakdown of one component is enough to invalidate the results.

The increase in system malfunction compared to the previous two years has two possible explanations. Firstly, the equipment (particularly the electronics) has aged - the two sets have now reached a state where a complete overhaul is a minimum requirement (including replacement of all circuitry). In fact, these two sets of equipment have been installed for two and three years respectively, almost without a break which, bearing in mind the harsh environment, could be the maximum expected life of the instrumentation. The second likely cause of the decrease in reliability is associated with the experience of the staff involved in the system maintenance. The equipment is complex, and it is vital that the maintenance should be undertaken by staff who are committed (in terms of priorities) and experienced (at least in the type of work and preferably in dilution gauging itself). Such staff requirements could not be met during this year and the quality of the data suffered accordingly.

The major alteration in staff practice has concerned the sampling lines. A close inspection showed that the lines retained a lot of particulate matter (and some even became blocked) even after a single gauging. A more vigorous approach to this aspect of maintenance was adopted, and the tubes were flushed with a high-pressure water-jet after each gauging. The cause of the decreasing injection rate was identified as corrosion of the inside of the Magnalatch valve, but the method of estimation (see App IV) was confirmed to be satisfactory.

The difficulties described above have resulted in only one satisfactory gauging (Figure A5.13) from the Stevenage experiment and two satisfactory gaugings (Figures A5.14 and A5.15) from Bracknell. The reduced number of satisfactory gaugings is unfortunate because these successful gaugings suggest that the problems of the previous two years have been eradicated. In particular, the use of the two samplers in parallel was found to be an improvement. It had been rare to need more than 24 samples at 2-minute intervals whereas the pairing of samples (Figs A5.13, A5.15) gives increased confidence in the results.

6. CONCLUSIONS

The primary aim of the research and development work described in this report was to produce a portable apparatus which could be deployed to define the stage-discharge relationship in existing storm sewers. It was hoped that it would then be possible to 'rescue', for hydrological research, records of water level which had previously relied on an assumed roughness coefficient for theoretical conversion to flow. This would require the apparatus to have been thoroughly tested against traditional flow measurement systems and to have been proved accurate and reliable in different situations. We have failed to do this for the following reasons:

(i) Dilution gauging is a specialist activity. Even with manual methods it is important to follow rigorous procedures, applied in a cramped and harsh environment, to ensure no contamination. Considerations of mixing, constancy of injection rate, storage of samples, and the analyses themselves, all require expert attention which is not always available.

(ii) The electronic system of chaining each operation in series worked well at first but showed an increasing failure rate with time due both to corrosive deterioration and to diminished enthusiasm on the part of the servicing technician.

Despite these drawbacks, which suggest to us that automatic dilution gauging is unlikely to be marketable as a viable package for use by the 'engineer in the street', it is possible to obtain good results under the ideal circumstances of having thoroughly cleaned equipment serviced by a dedicated technician. One further modification to improve the confidence with which these results are interpreted might be to log accurately the time of each sample. Although the number of successful gaugings was rather small, it would seem that, if all the

necessary resources of equipment and expertise are available, it is possible to establish a stage discharge relationship which is preferable to that based on assumed roughness values.

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APPENDIX I EQUIPMENT SUPPLIERS

i **Sampler**

Automatic Liquid Samplers Ltd 4BE sampler

Automatic Liquid Samplers Ltd
Unit 11
Bordon Industrial Estate
Bordon, Hants GK34 9HH

ii **Magnalatch valve**

Skinner 12V Magnalatch valve

Arca Controls Ltd
Queens Engineering Works
Bedford MK40 4JB

iii **Mariotte Bottle**

from Institute of Hydrology workshop

iv **Pulse generating circuit for Magnalatch valve**

from Institute of Hydrology workshop

APPENDIX II Circuit diagrams

1. Pulse Generating Circuit for the Magnalatch valve.

This circuit (Figure A2.1) is used to control the injection from the Mariotte. The circuit has two inputs, a 12 volt power supply and a switch input provided by the output plug of the upstream sampler. Whenever the output plug provides a short circuit (that is when the sampler is operational) this circuit sends a pulse to open the Magnalatch valve. Conversely whenever the output plug goes to open circuit a pulse to shut the valve is transmitted.

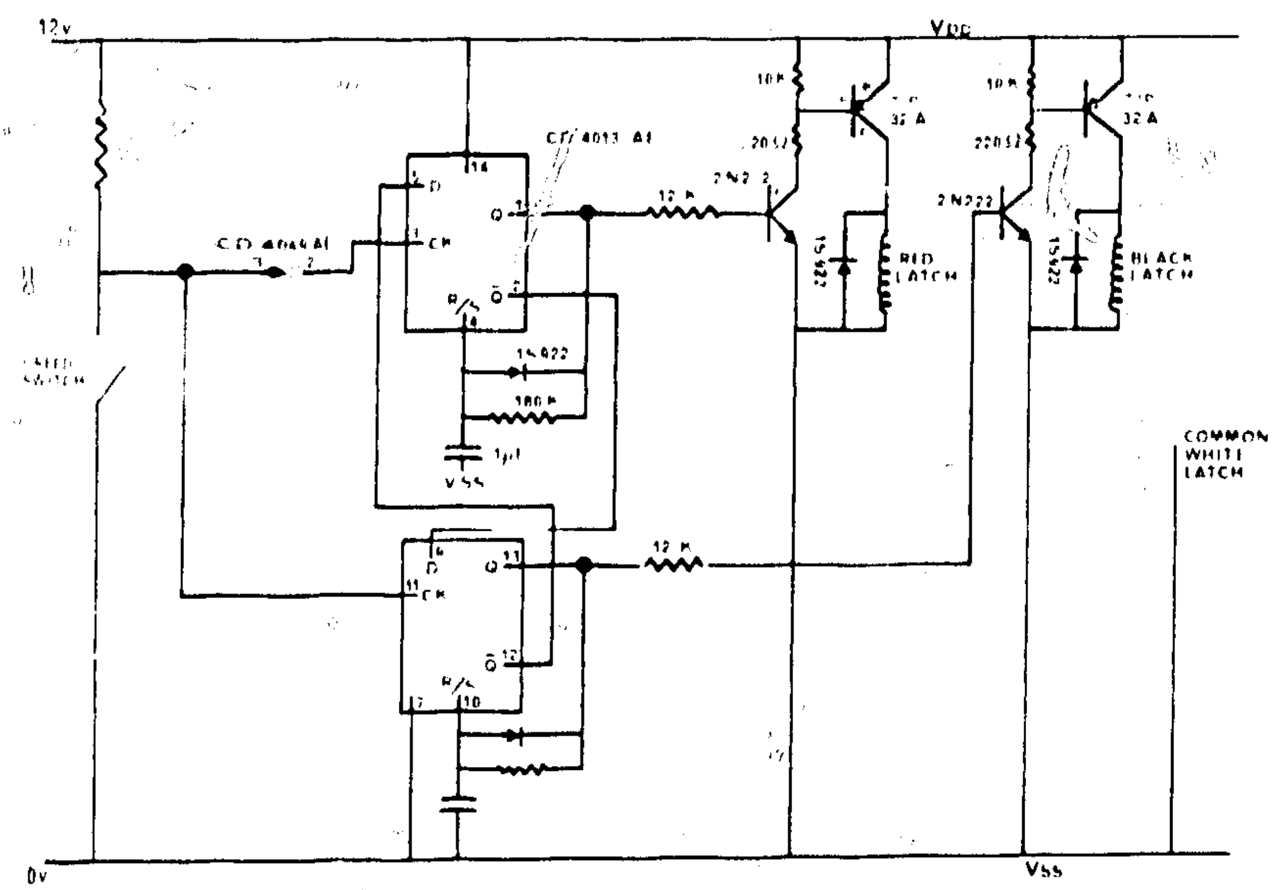

FIGURE A2.1 PULSE GENERATING CIRCUIT FOR MAGNALATCH

2. Sampler Circuit

This circuit (Figure A2.2) controls the operation and triggering of each of the [illegible]e samplers. The input and cascade plugs, the control switch a[illegible]ttom microswitch are standard fixtures in the samplers as supp[illegible] output and logger plugs, the HOLD switch (marked M-T switch i[illegible]2.2) and the relay were appended by the IH Instrument Section.

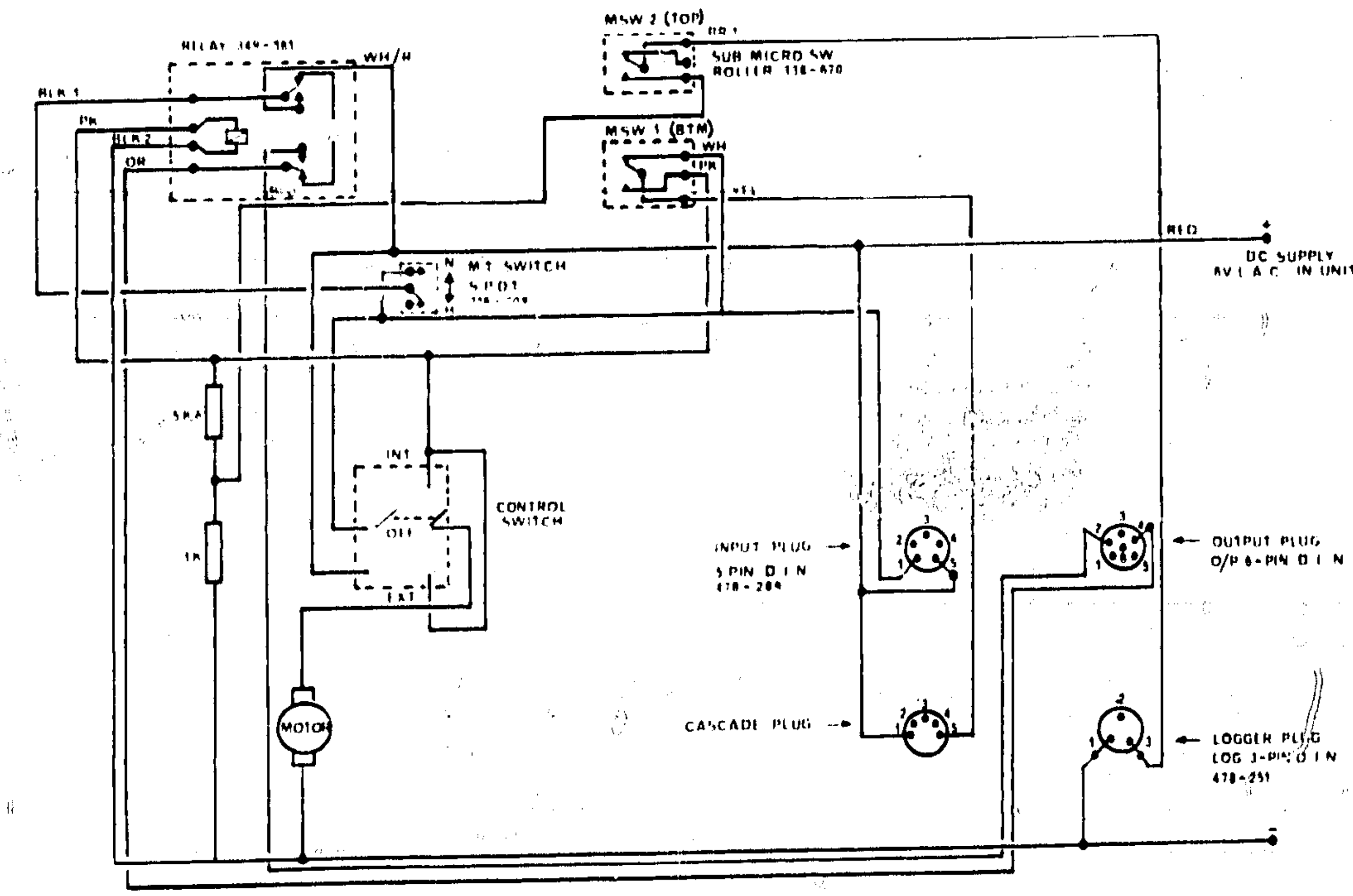

FIGURE A2.2 CONTROL CIRCUIT FOR AUTOMATIC SAMPLER

APPENDIX III Capital cost of equipment

Estimated capital costs for dilution gauging and equipment - October 1976.

		£
3 x Northants sampler complete	3 x 360	1080
+ surcharge for non-standard clocks	3 x 10	30
1 x Mariotte bottle (IH Workshop)	approx.	100
Magnalatch valve		10
Switching circuit for Magnalatch (IH Workshop)		20
Extra bottles for exchange of samples		30
Spare nickel-cadmium batteries		20
Cables and extra connecting plugs		20
TOTAL		£1310

This estimate excludes the cost of the depth measurement and logging system.

APPENDIX IV Field procedure

1. Preparation for field visit

1.1 Check list of equipment

- A. new set of bottles for each sampler, thoroughly rinsed, dried and capped.
- B. caps for bottles in the field, rinsed and dried.
- C. fully recharged nickel-cadmium batteries for the samplers.
- D. bucket and rope to lower equipment into manhole.
- E. replacement tracer in 15 litre container, with appropriate tubing.
- F. container of fresh water for washing sampling tubes, with freshwater tubing.
- G. Allen key and screw driver to adjust triggering level.
- H. plastic container and watch to test the injection rate of Mariotte bottle.

1.2 Preparation of tracer.

The tracer should be prepared in the laboratory at the correct concentration and taken into the field in bulk. The concentration to which the solution is prepared is dependent upon the maximum flow one expects to measure.

Bungs seal much better than the screw tops normally provided on containers. To ensure adequate mixing in the Mariotte bottle, each new batch of solution should be made up such that its concentration is as close as possible to the concentration of the previous batch.

After the solution is mixed, the bottle, together with all its tubing, should be washed down thoroughly. The tubing should never be disconnected from the bottle and the free end of the tubing always closed. It cannot be emphasised too strongly that the tracer container and its tubing should not come in contact with any other equipment.

2. Field Operation

2.1 The downstream site

Work should always be carried out at the downstream site first. If the upstream site were serviced first, there is some danger of contaminating the downstream site with concentrated tracer solution.

(Presuming that the equipment has previously been activated i.e. there are samples to be taken away)

A. rinse hands thoroughly, especially if there has been any contact with the tracer container.

B. remove the bottles from the sampler, capping each bottle as soon as it is disconnected.

C. remove the bottles from the manhole.

D. rinse the sampling lines and the tubes within the sampler with fresh water.

E. force air through all the lines, particularly the lines within the sampler, to minimise dilution to the next sample.

F. rinse hands before touching the instrumentation.

G. replace sampler batteries if required.

H. adjust triggering level.

I. load the samplers with fresh bottles.

J. evacuate the bottles.

K. check that the 'hold'/'normal' switch is in the desired position.

L. check that the switch inside sampler is in 'external' position.

M. check that the sampling lines are connected to the sampler.

N. check that the 'input' plug is connected to the depth recorder.

O. check that the 'cascade' plug is connected to the 'input' plug of the second sampler if there is one.

P. check that the 'logger' plug is connected to the logger.

Q. check that the sampler rotor arm is down.

R. disconnect the upstream site by removing the 'output' plug and activate sampler by raising trigger.

S. connect 'output' plug to the upstream site.

If the equipment has not been activated since the last visit only items K through to S from the above list should be necessary.

2.2 The upstream site

The upstream site should only be entered after work has been completed downstream. The sampler at the upstream site should be treated in an identical fashion to the samplers at the downstream site. Care must be taken that the samples once removed from the manhole do not become confused with samples from the downstream sampler.

The refilling of the Mariotte bottle with fresh solution requires the utmost care to avoid contamination of the surroundings with concentrated solution. In transport the container of fresh solution and its tubing should not be allowed contact with any other equipment.

The container should not be lowered into the manhole. The bung on the Mariotte vessel should be removed and washed immediately in the sewer flow and put aside. Fresh solution should then be added from the container outside the manhole through the interconnecting tube, allowing all solution to drain from the tube.

After sealing the bottle, solution should be run out until the bottle is bubbling. The injection rate should be tested by collecting a timed quantity of solution, which should be retained for later analysis. When replacing the bung in the top of the Mariotte bottle there will be a tendency to force concentrated solution out of the air inlet. This can be avoided by opening the valve and letting solution run out while the bung is gently replaced. If this is not done then the solution will spread easily and contaminate the site.

APPENDIX V

Figures illustrating dilution gauging results compared to theoretically measured flows.

A5.1	Stevenage	1.11.76
A5.2	"	6.11.76
A5.3	"	12.11.76 (1)
A5.4	"	12.11.76 (2)
A5.5	"	28.11.76
A5.6	"	25. 9.77
A5.7	"	31.10.77
A5.8	"	6.11.77
A5.9	"	20.11.77
A5.10	"	23.11.77
A5.11	Bracknell	23.11.77
A5.12	"	10.12.77
A5.13	Stevenage	19.11.78
A5.14	Bracknell	12. 1.78
A5.15	"	10.12.78

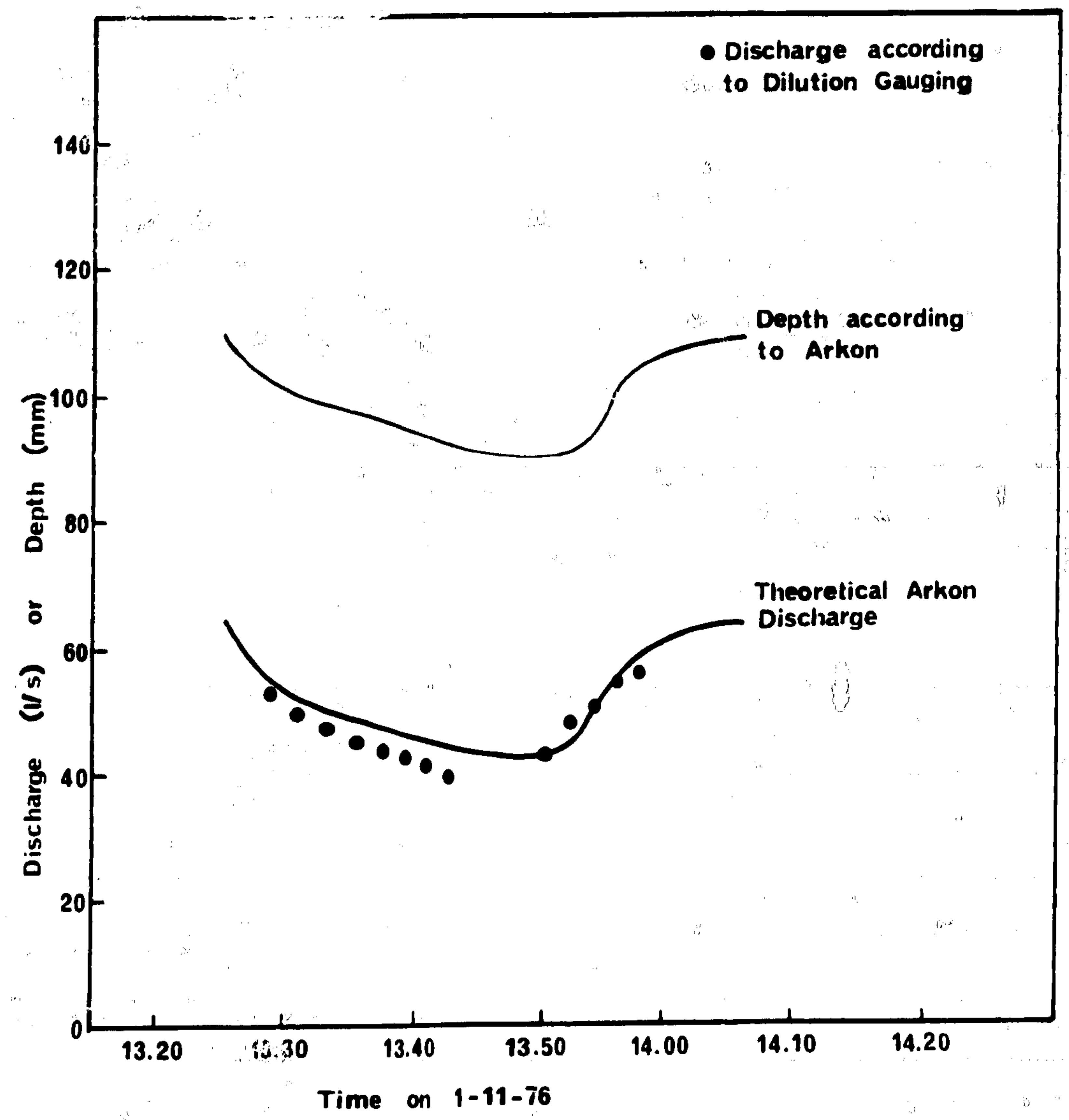

FIGURE A5.1 DILUTION GAUGING RESULTS, STORM 1 ON 1-11-76

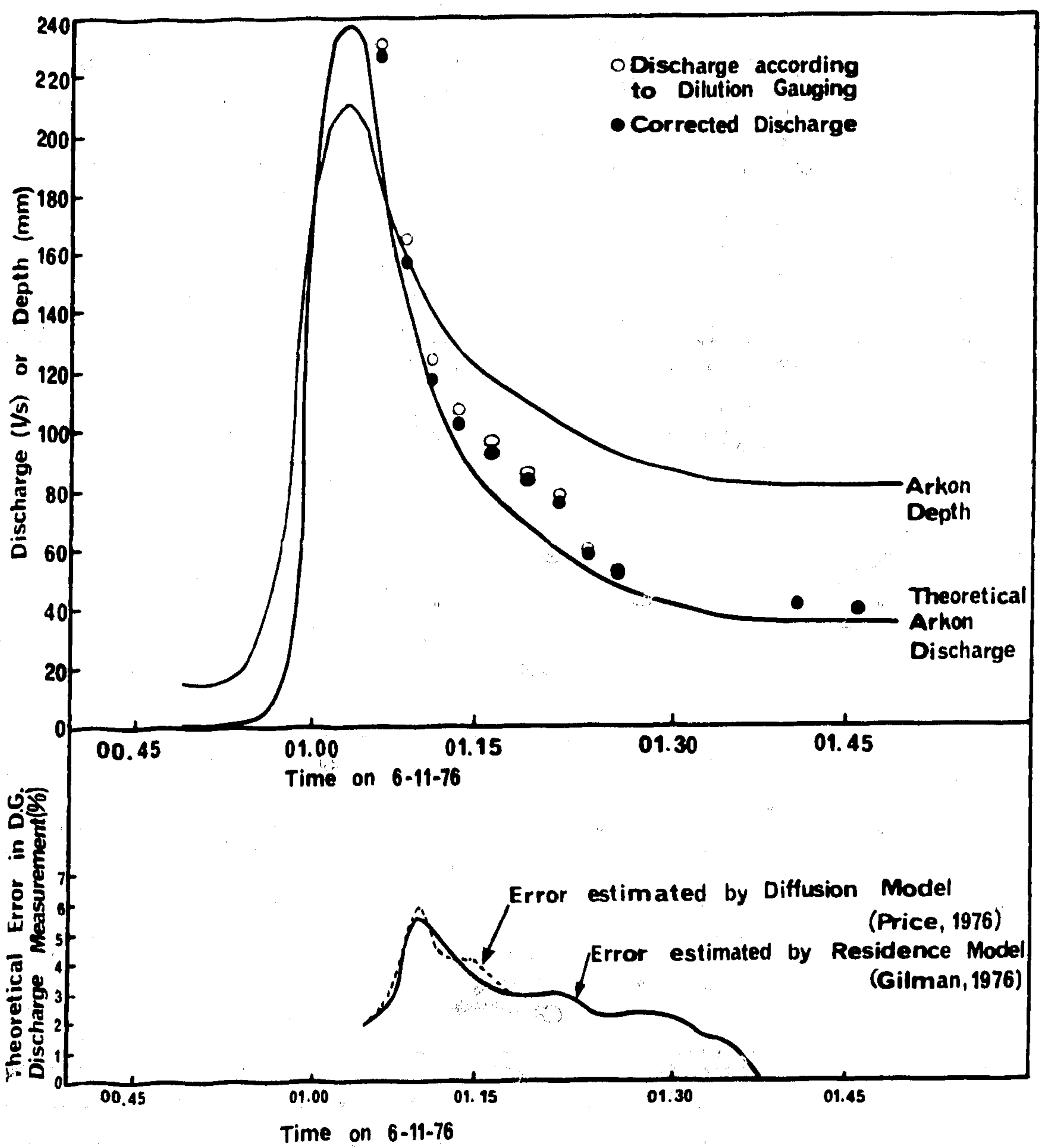

FIGURE A5.2: DILUTION GAUGING RESULTS, STORM 2 ON 6-11-76

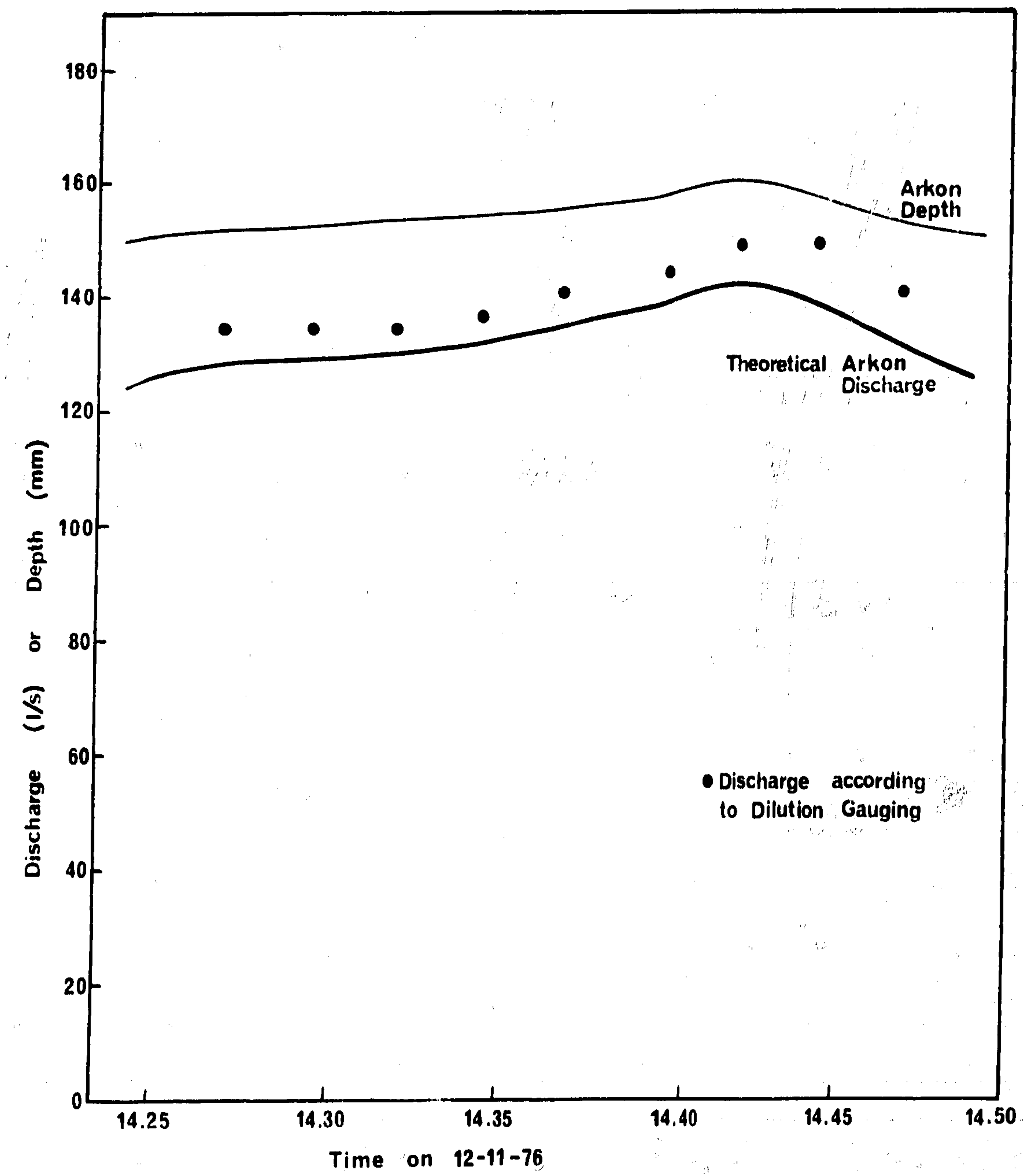

FIGURE A5.3 DILUTION GAUGING RESULTS, STORM 3 ON 12-11-76 (1)

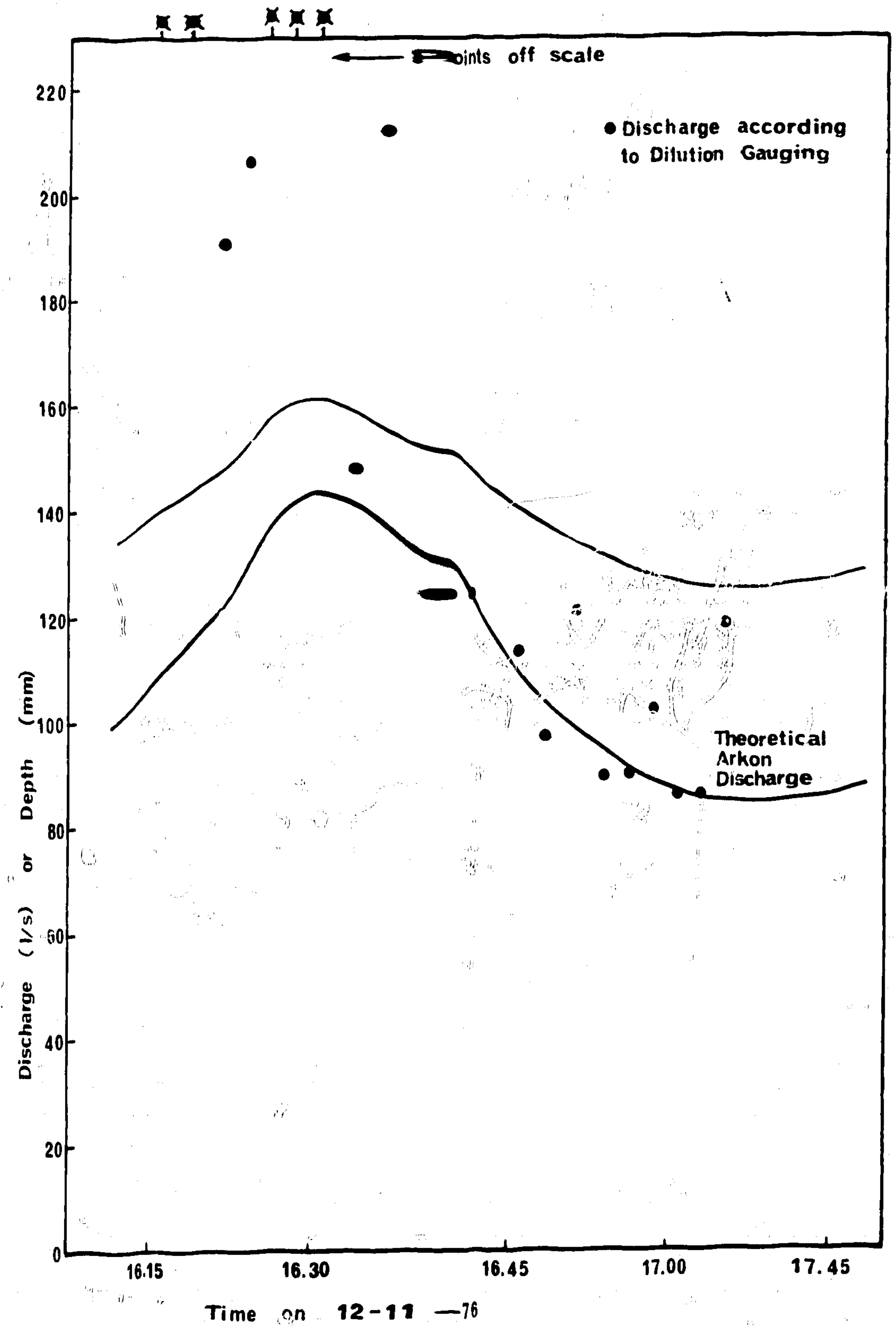

FIGURE A5.4 DILUTION GAUGING RESULTS, STORM 4 ON 12-11-76 (2)

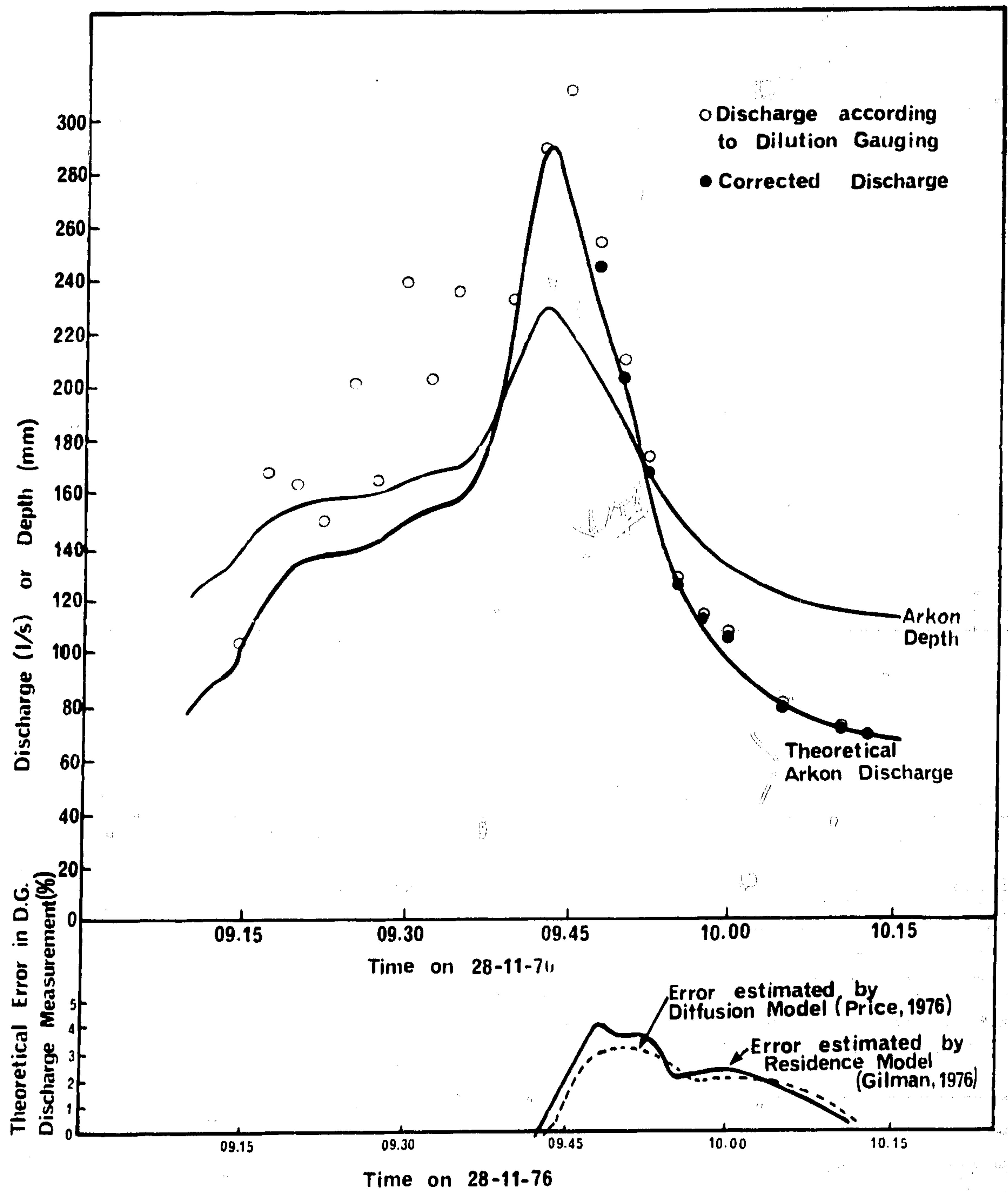

FIGURE A5.5 DILUTION GAUGING RESULTS, STORM 5 ON 28-11-76

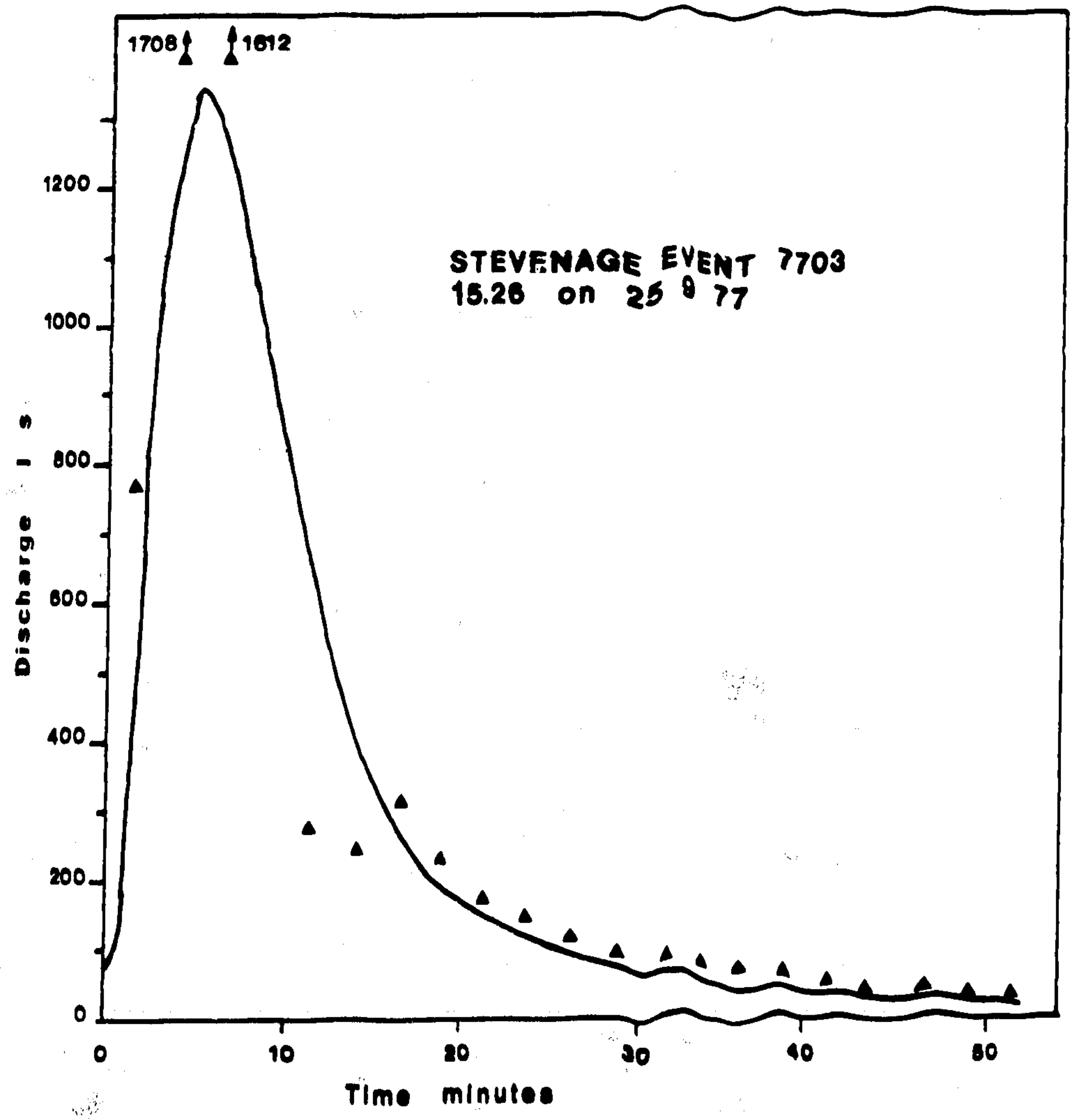

Figure A5.6: DILUTION GAUGING RESULTS Storm 7703 on 25 9 77

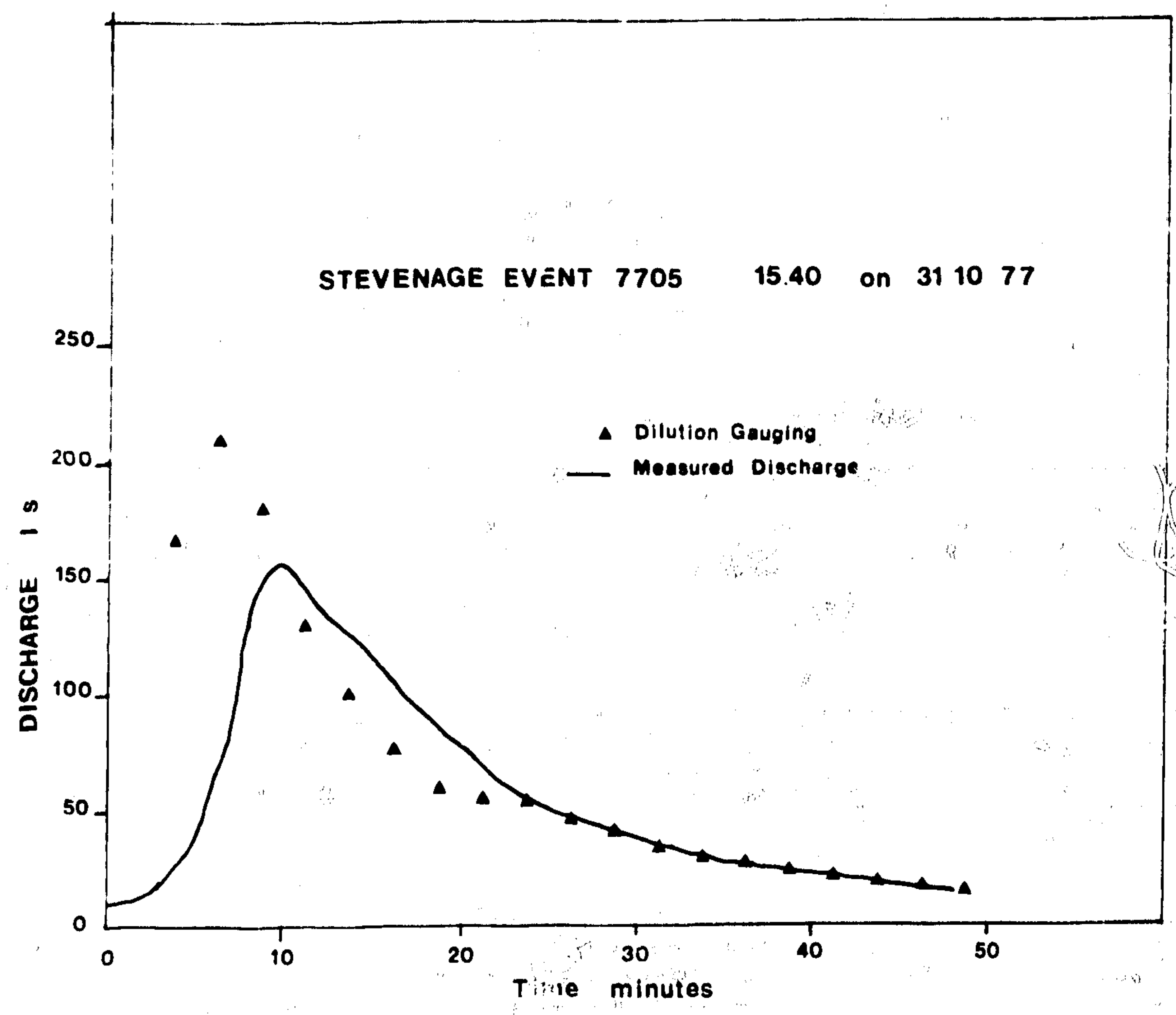

Figure A5.7 DILUTION GAUGING RESULTS Storm 7705 on 31 10 77

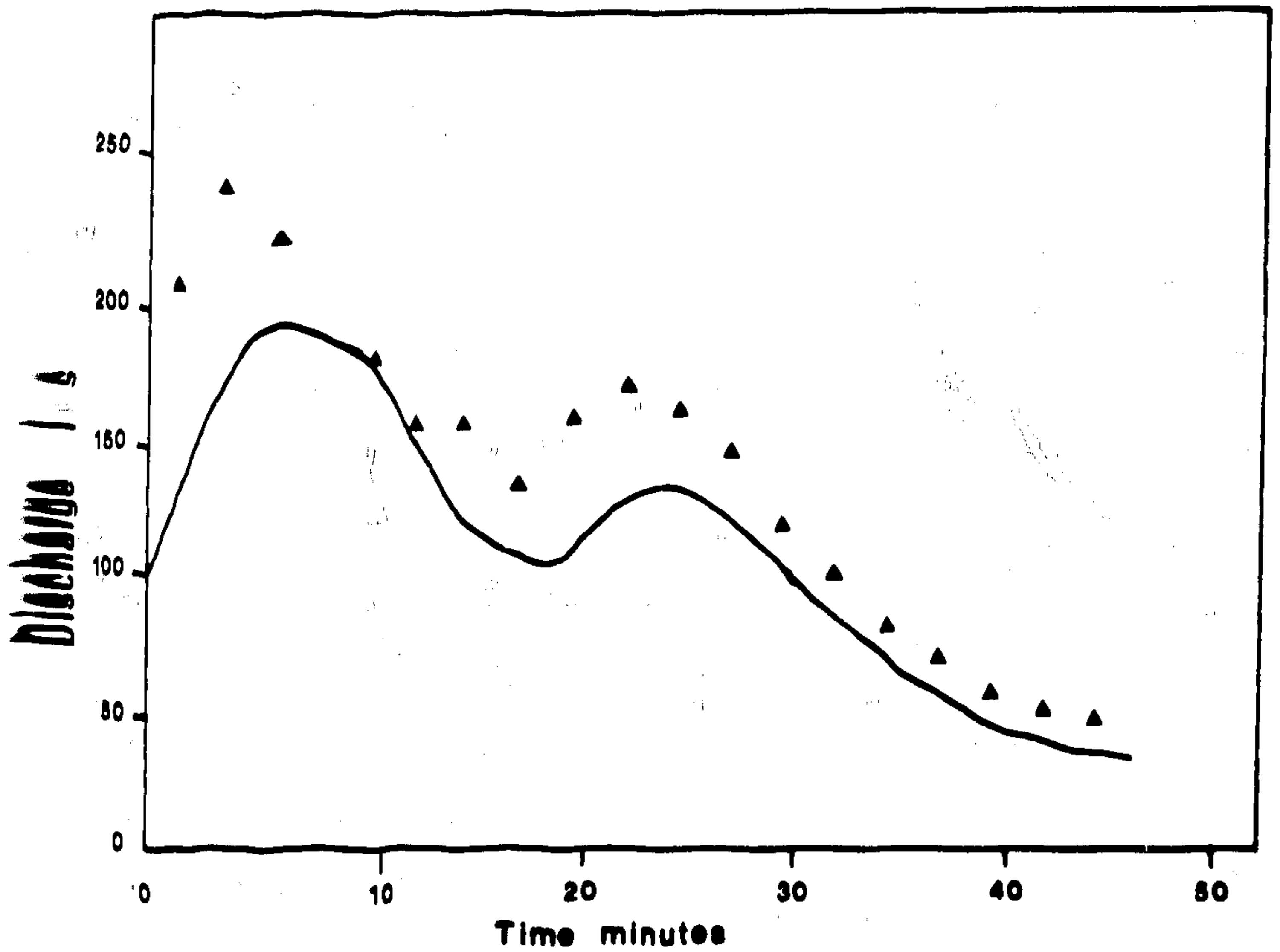

Figure A5.8 STEVENAGE EVENT 7707 15.17 on 6 11 77

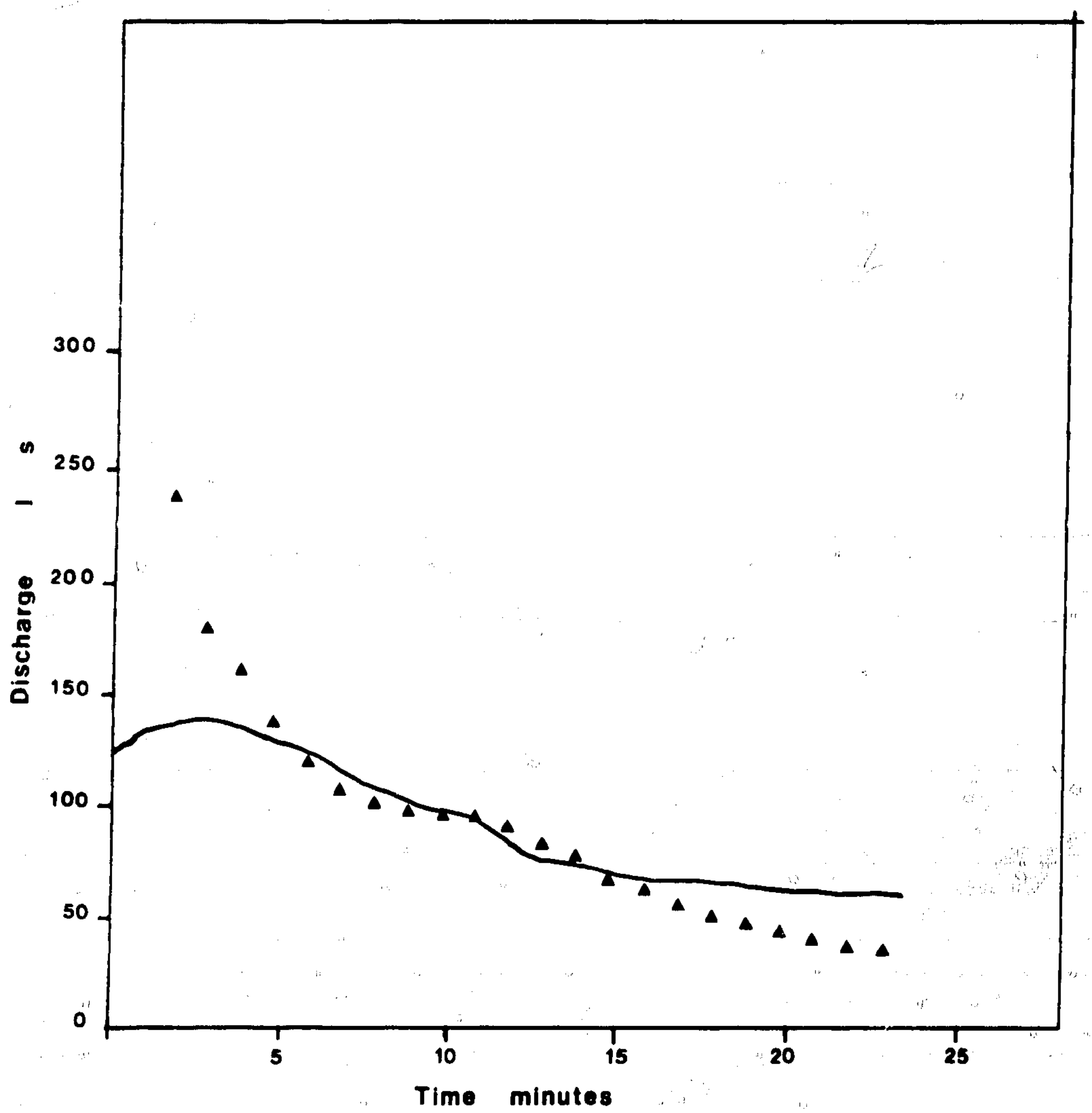

Figure A5.9 STEVENAGE EVENT 7708 6.30 on 20 11 77

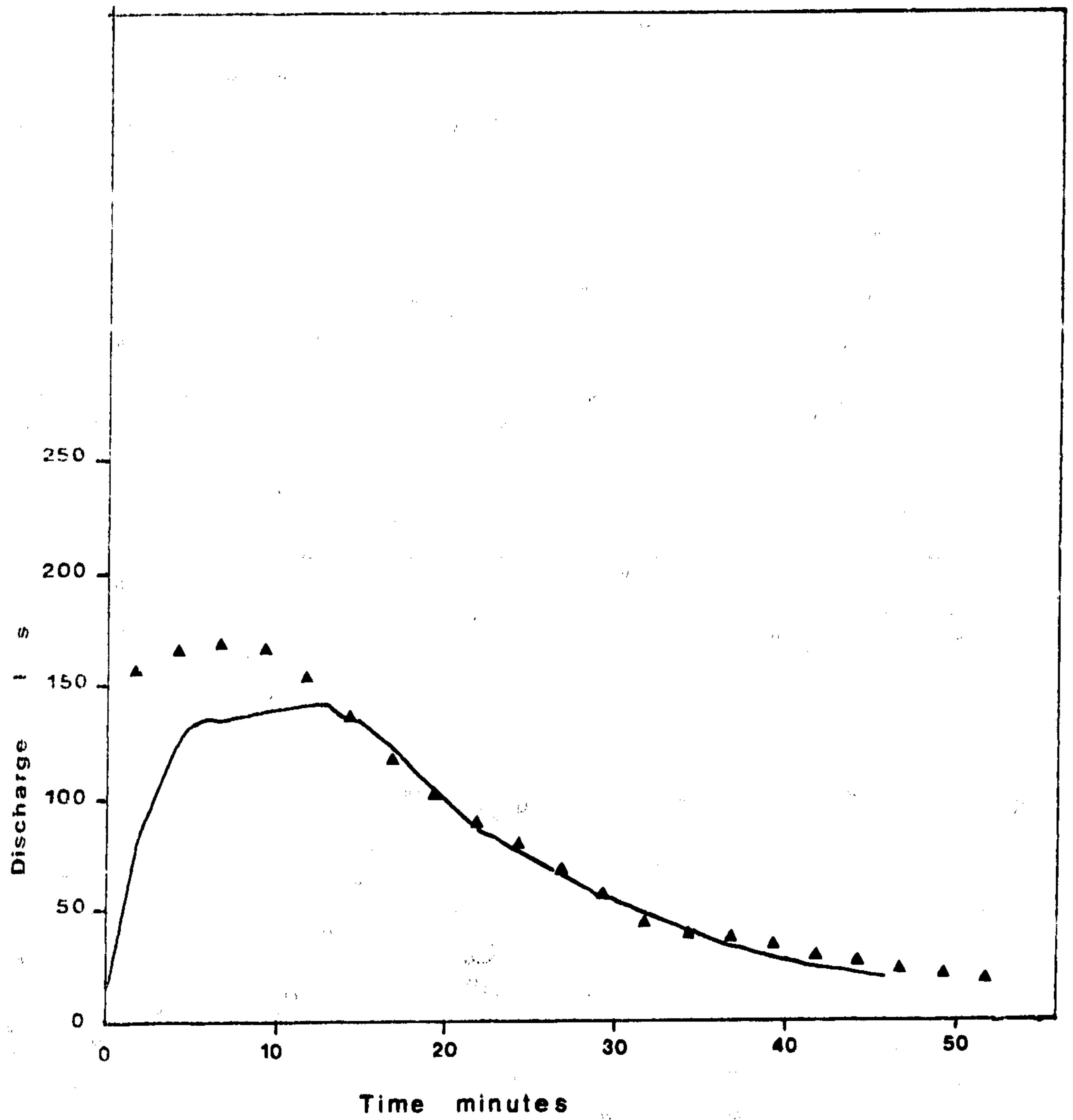

Figure A5.10 STEVENAGE EVENT 7709 21.56 on 23 11 77

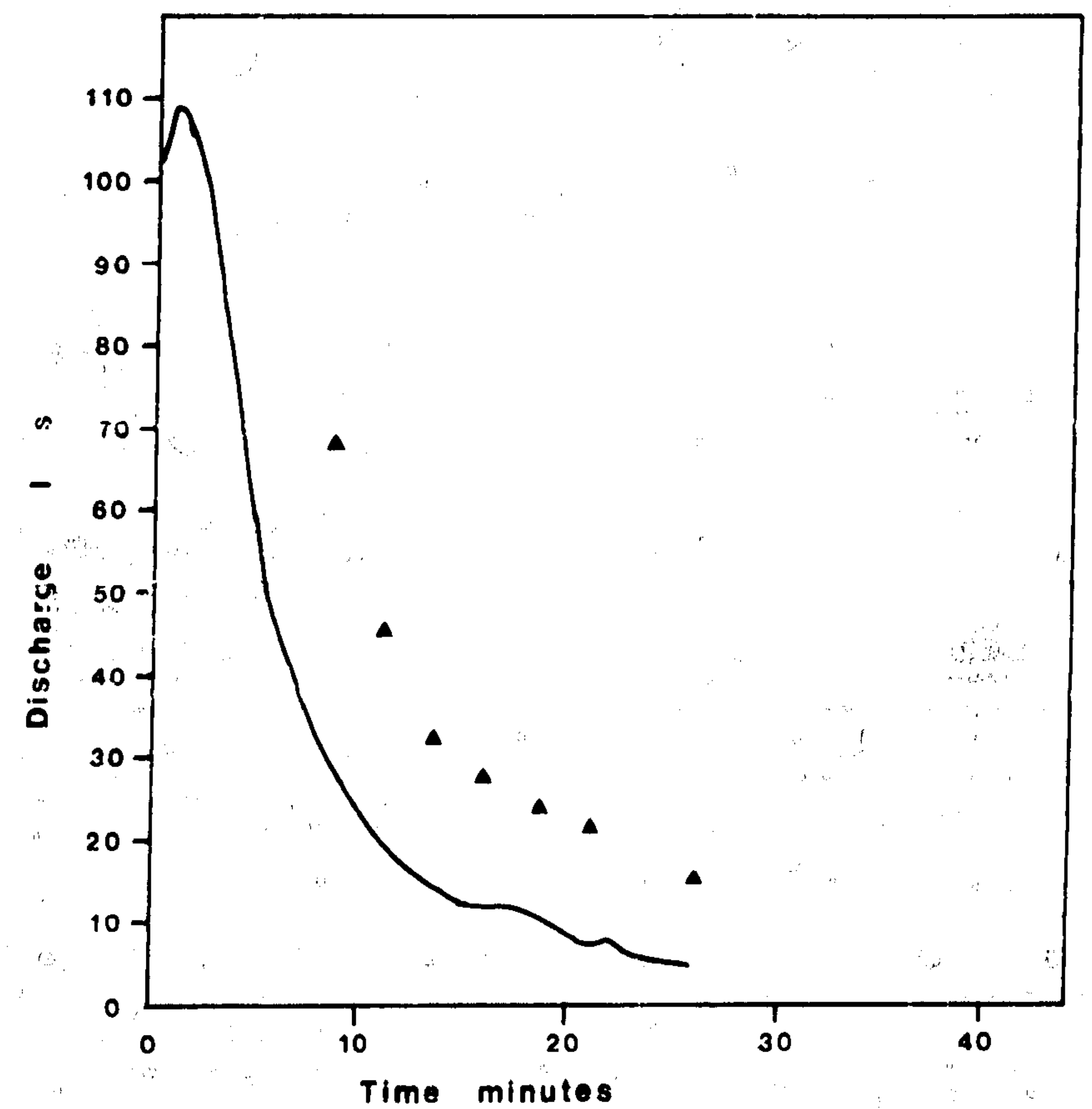

Figure A5.11 BRACKNELL EVENT 7701B

23.13 on 23 11 77

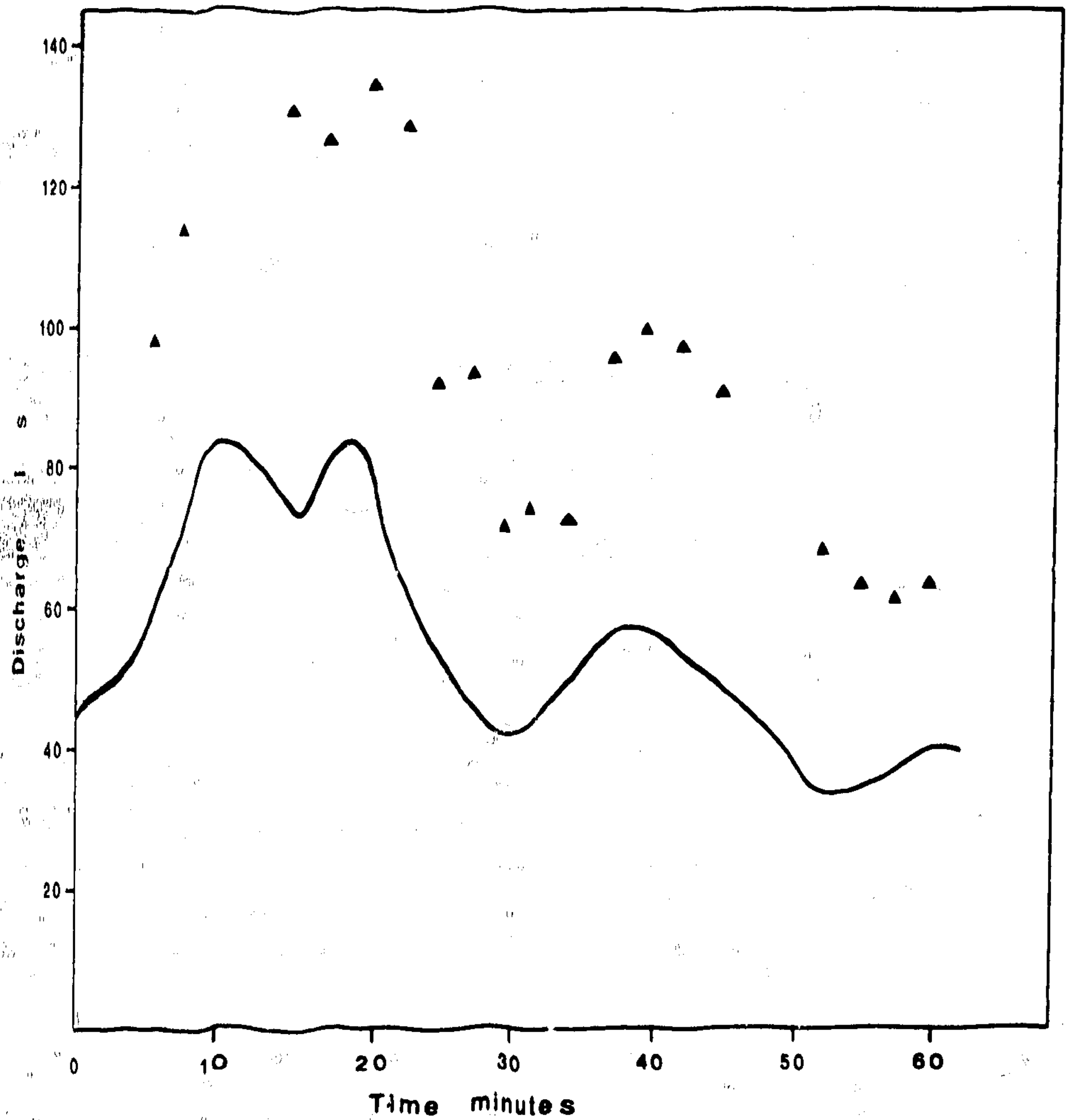

Figure A 5.12 BRACKNELL EVENT 7702B

01.29 on 10 12 77

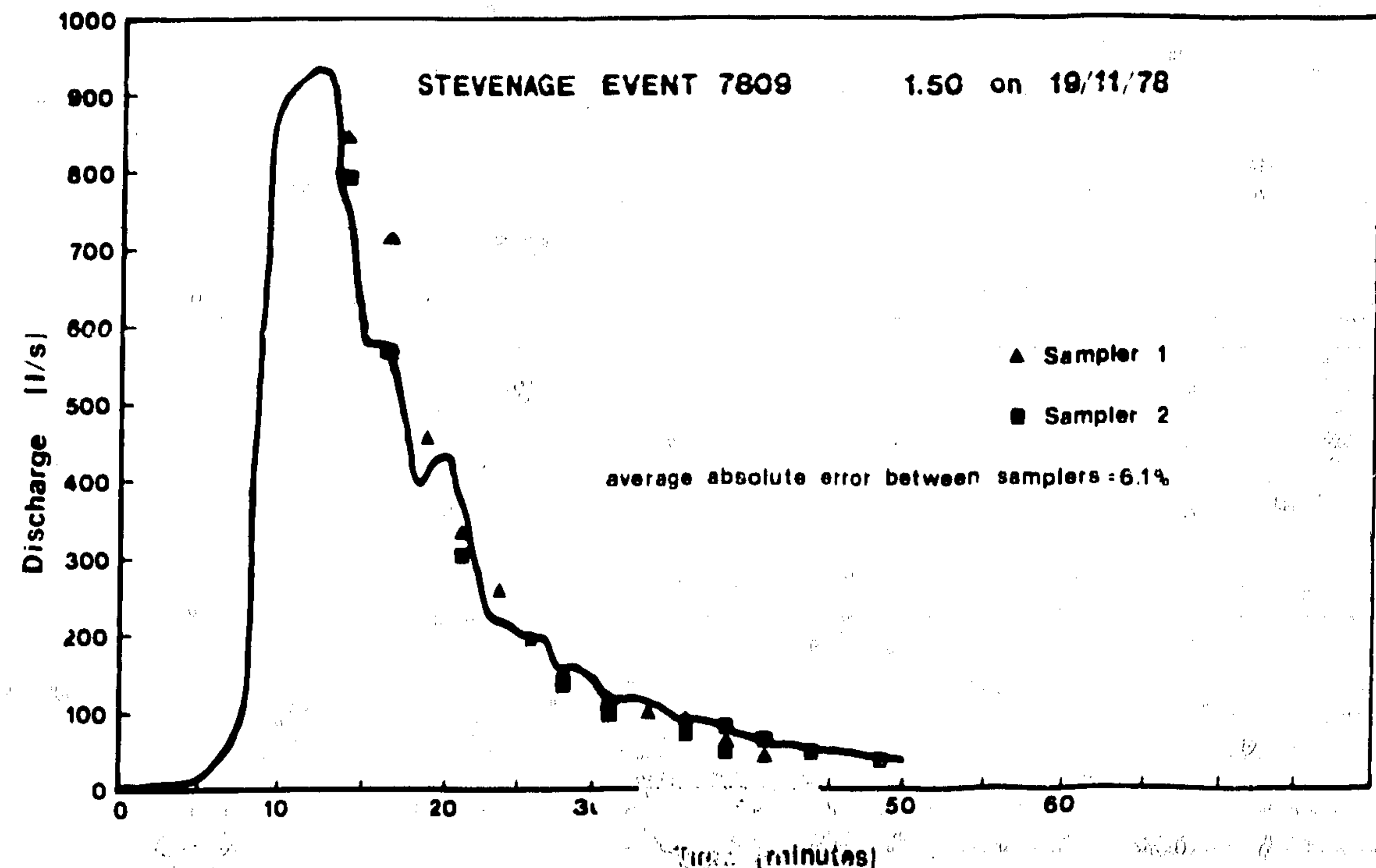

Figure A5.13 Dilution gauging results, storm 7809 on 19/11/78

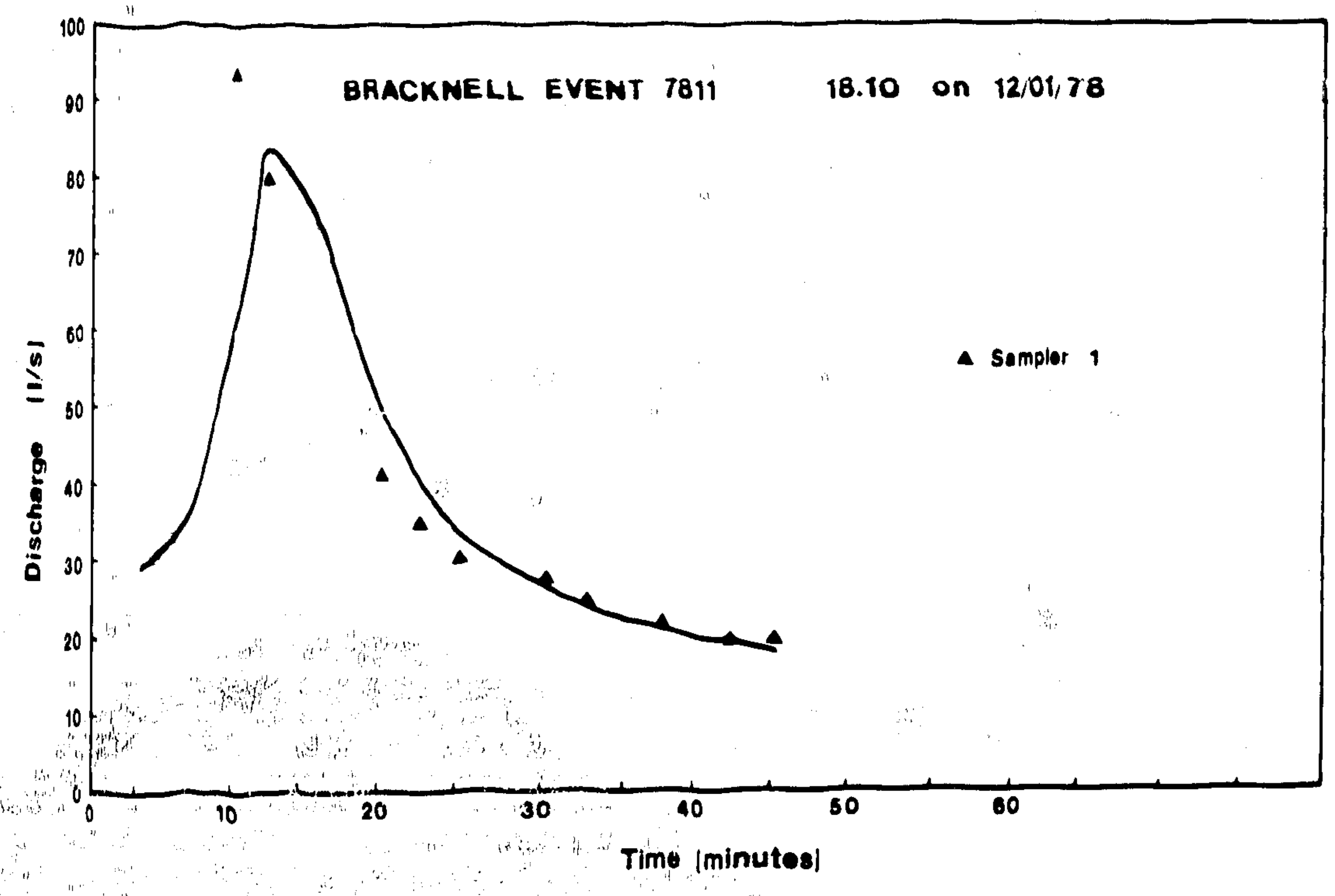

Figure A5.14 Dilution gauging results, storm 7811 on 12/01/78

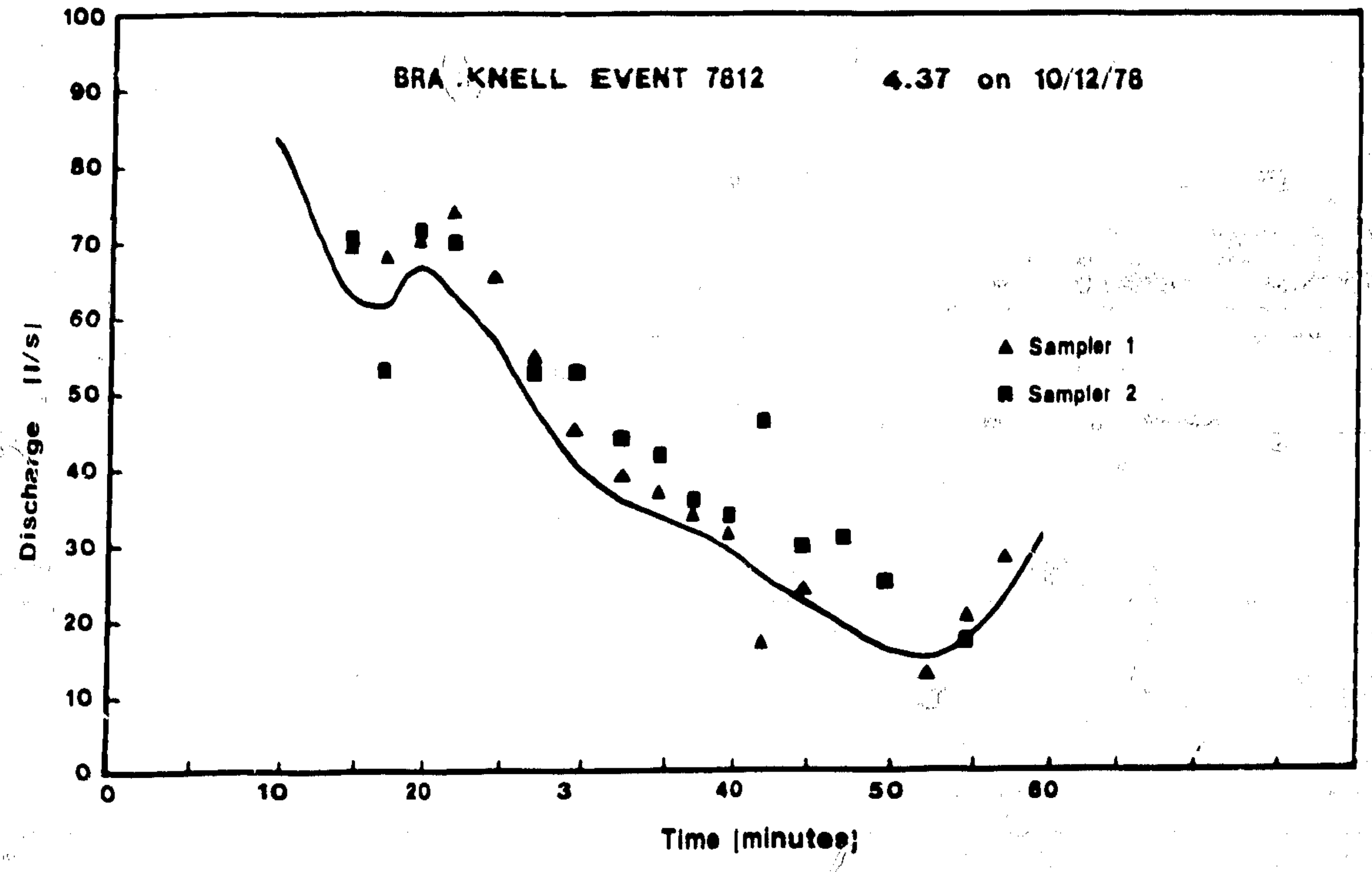

Figure A5.15 Dilution gauging results, storm 7812 on 10/12/78