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A SYSTEM FOR THE DIGITISATION AND PROCESSING OF V-NOTCH WEIR HYDROGRAPH RECORDS

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PREFACE

The exercise outlined in the following note was carried out as part of a project studying geochemical cycling in an upland grassland catchment near Plynlimon, mid Wales (ITE Project 594). A general introduction to this project is available as Bangor Research Station Occasional Paper No. 2.

1 Introduction

Stream discharges from the experimental sub-catchments within the Wye watershed at Plynlimon have been monitored using 90° V-notch weirs and stage height recorders furnished by the Institute of Hydrology. The recording system is simple and consists of a float with a pen attached which scribes on a rotating drum. The drum is driven by a clock and thus a permanent record of water level can be obtained for a specified fixed time period. Clocks usually operate over a week or a month.

Excellent descriptions of V-notch weirs, their use and the theoretical background to them can be found in Gregory and Walling (1973), Ingle-Smith and Stopp (1978) and the British Standards Institution (1964). A simplified and brief description is given here so as to place the data processing into context.

Figure 1a shows a general representation of V-notch weir installation, a sectional view of the stream is shown in Figure 1b. In this diagram the water level recorder has been omitted. The value H, Figure 1b, is the head of water flowing over the weir. In order to obtain the value of H from the stage height record, it is necessary to find the value of the stage height for which H = 0. That is the stage height at which water just commences to flow over the weir. For the Plynlimon weirs, this value was determined in the field and is referred to as the datum level of the weir.

The head of water H is related to stream discharge by formulae such as $Q = 1.38\ H^{2.5}$ (Gregory and Walling 1973). A logarithmic

Figure 1a V-notch Weir Installation

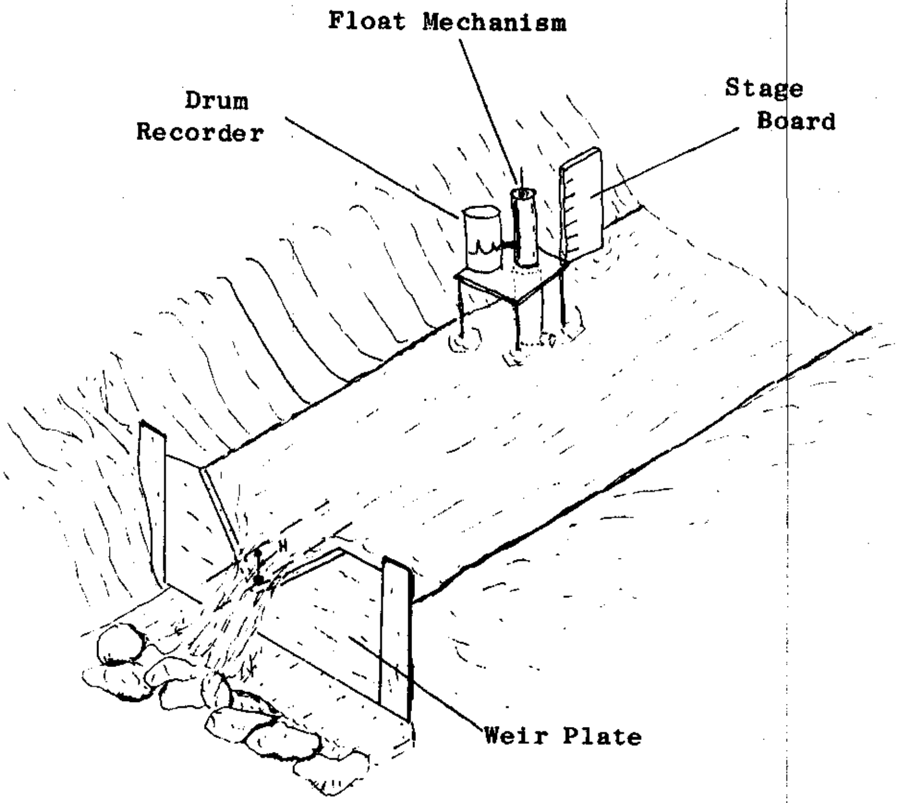
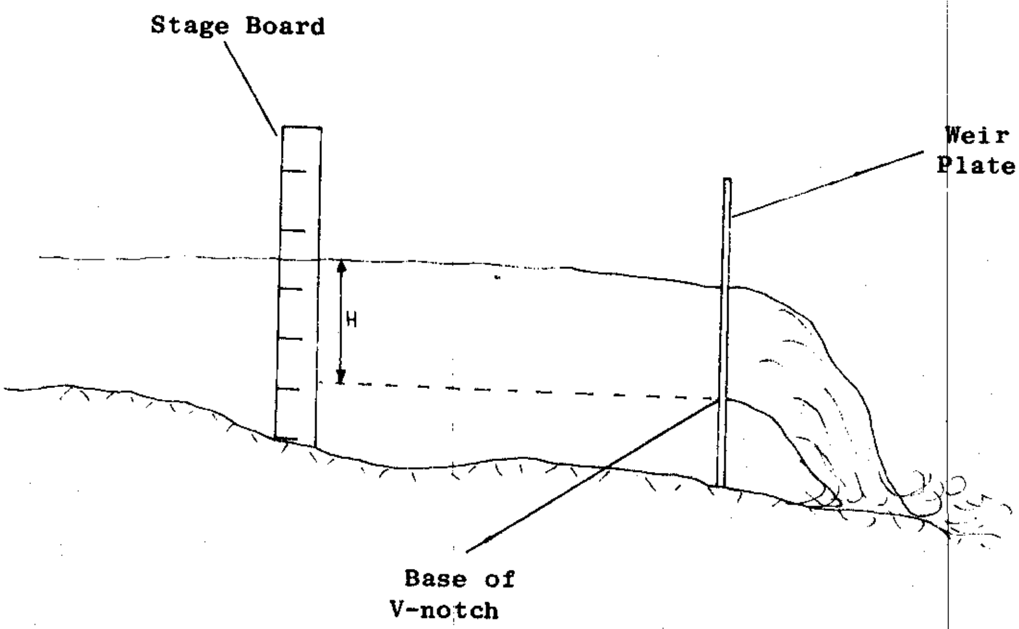


Figure 1b V-notch Weir - Section.



calibration curve provided by Institute of Hydrology staff has been used in this study however.

The purpose of this document is to describe the techniques used to obtain a continuous record of stream discharge from the water level chart records. This has involved the conversion of the chart records to numerical data using a Reichert-Jung MOP II Digitiser with subsequent processing of this information using the PDP 11-34 Computer at ITE Bangor. The stream discharge data have been used in conjunction with stream water chemistry to calculate solute losses from the experimental catchments.

2 Description and Preparation of Chart Records

The charts used with the water level recorders are of the standard Munro type, and the data were colleted using weekly time periods. A typical chart for a week in the spring of 1981 is shown in Figure 2. Unfortunately the charts are too long for the size of the MOP digitising tablet, so they have been divided into three separate "frames" as illustrated in Figure 2. Frame one starts at the first six hourly division to the right of the start of the record. This point was chosen to accommodate errors in marking the beginning of the record in the field. Frame one measures 24 cm along the time axis. Frame two extends to the end of the chart and frame three runs from the start of the chart to the beginning of frame one. Frame boundaries are drawn on the chart and the corners marked with crosses. The weir datum is also drawn on the chart so that water levels can be referred directly to it. The datum line is positioned on the chart using the stage height values read from

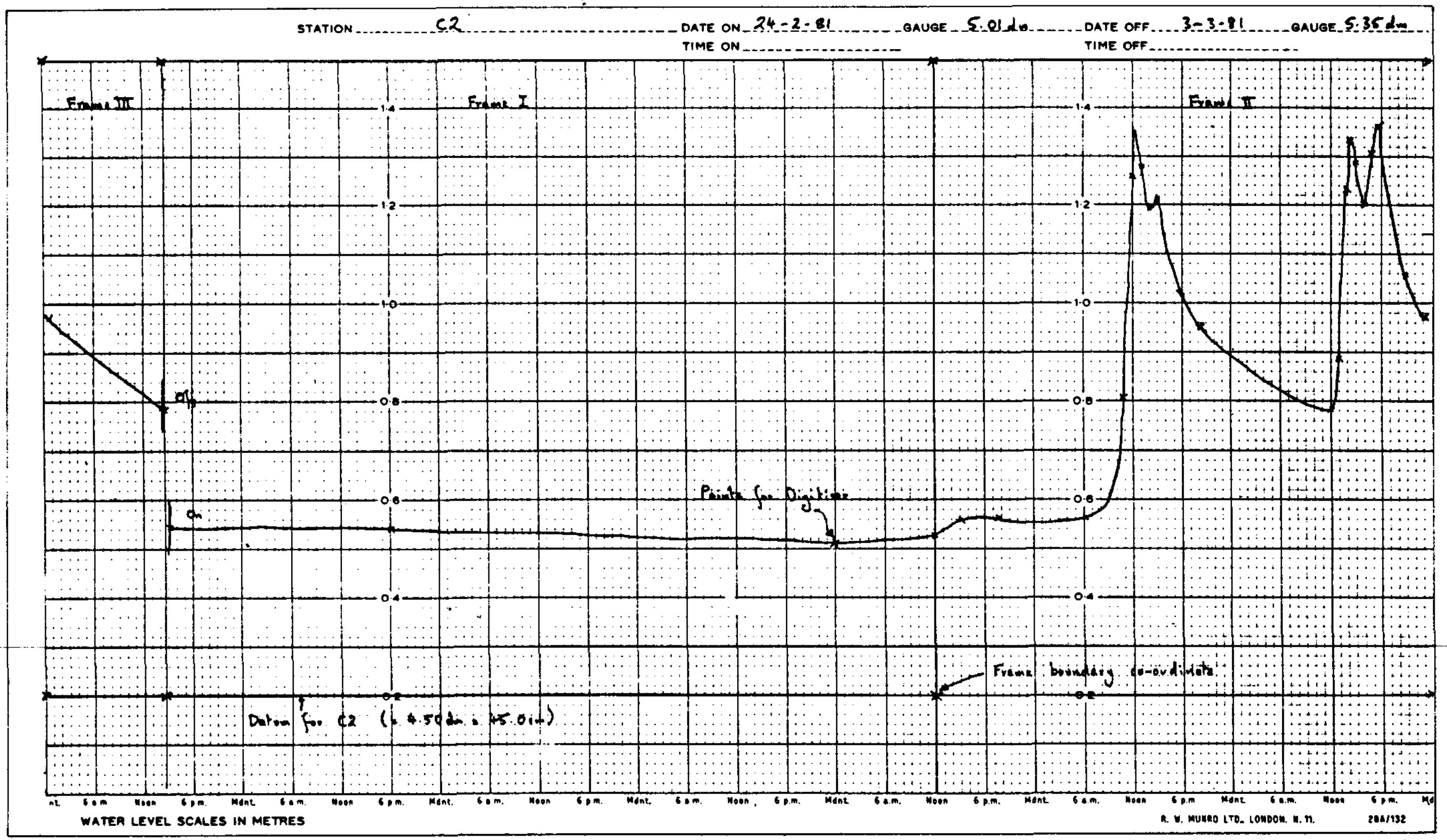


Fig 2 Chart Record

staging board when the charts are changed at the beginning and end of each week. If a discrepancy occurs between these values, the midpoint is taken as the datum. Occasionally, the datum line will occur below the bottom of the chart. In this situation, the chart has to be extended with a suitably sized piece of graph paper, and the datum drawn on this. The maximum length of the frame boundaries along the height axis is approximately 30 cm above the datum line.

The points to be digitised are marked with crosses and are selected on the pen record "by eye" so as to divide the record into a series of straight line segments. This means that the number and positioning of the points is dependent on the complexity of the chart. Thus the operator has to decide upon the number of points required to define each portion of the chart.

In some instances large storm peaks may exceed the upper boundaries of the frames. Where this occurs the points at which the peak crosses the boundary are marked. Such a peak is "flagged" in the digitised data with a zero entered via the MOP keyboard. The height of the peak above the boundary can then be measured and entered directly into the data during editing. An example of the procedure is given in the section on preliminary editing (Section 4.1).

3 Digitisation of Charts

The detailed operating instructions for digitisation are given in Appendix 1. The directions assume that the MOP is to be used directly "on-line" to the PDP-11 computer in conjunction with a VDU (Visual Display Unit). Data entered from the digitiser may be listed using the Basic program COLUMN.BAS, which produces formatted listings in columns, or via the PIP utility directly to the line printer.

The data file names are configured in the following manner:

SnDm.DAT

Where Sn - alpha-numeric code of the site, e.g. C4, W2

D - refers to digitiser

m - sequence number of file e.g.

C4D1.DAT

C4D2.DAT

Each data file should contain a complete set of weekly records with no gaps. This facilitates the insertion of any missing weekly records at a later stage. Thus, for example, for the weir at site C4 the data files might be:

C4D1.DAT containing data for weeks 32-38 inc

C4D2.DAT containing data for weeks 40-41 inc

C4D3.DAT containing data for weeks 42-46 inc

Data for weeks 39 and 41 are absent because the charts were spoiled or incomplete. It is a good idea to keep a record of each data file as it is created so as to avoid any confusion at later stages of processing.

Owing to certain problems with the compatibility of the MOP with the PDP-11 computer, it is advisable to digitise charts in batches of about six at a time and then to exit from the MOP routine. It is also preferable to operate the MOP during periods when there is a low demand on the computer from other users. Significant data loss may otherwise occur between the digitiser and the computer. It is a worth while practice to list the data files created after each batch of new charts has been digitised.

4 Data Processing

4.1 Preliminary Editing

An example of a page of digitised data is given in Figure 3. This was produced using the COLUMN.BAS program. Each complete full line of digits refers to a point and is the co-ordinate of that point in mm, referred to the origin position of the MOP tablet. A typical point might be

0 0.274334E+02 4 0.117977E+03 5

The single digits 0, 4 and 5 may be ignored, and this line refers to a point with coordinates

x = 27.4334 mm (0.2734334 x 10^2 mm)

y = 117.977 mm (0.117977 x 10^3 mm)

The actual values of these coordinates are unimportant as they are related to the co-ordinates of the enclosing frame for the purposes of processing.

The data listings can now be scanned visually and any obvious errors corrected. Spurious characters are often found at the beginning and end of the data files. These are printed when the system is switched from VDU to MOP and back again and should be removed.

Storm peaks exceeding frame boundaries which were referred to earlier should be edited in here. A simple storm peak

```
0 0 6   — Trip No. = φ49
0 4 6
0 9 6
0 0.227035E+02 4 0.254063E+02 5   } First
0 0.233117E+02 4 0.246293E+03 5   } Frame
0 0.266158E+03 4 0.245009E+03 5   } Co-ordinates
0 0.265753E+03 4 0.246631E+02 5   }
0  9 6
0 0.245279E+02 4 0.679754E+02 5
0 0.295145E+02 4 0.681106E+02 5
0 0.313525E+02 4 0.222576E+03 5
0 0.320958E+02 4 0.166020E+03 5
0 0.326363E+02 4 0.159658E+03 5
0 0.334472E+02 4 0.166830E+03 5
0 0.360148E+02 4 0.131997E+03 5
0 0.381095E+02 4 0.121018E+03 5
0 0.464206E+02 4 0.104396E+03 5
0 0.593940E+02 4 0.946656E+02 5
0 0.687863E+02 4 0.903411E+02 5
0 0.706107E+02 4 0.893951E+02 5
0 0.722999E+02 4 0.925709E+02 5
0 0.792596E+02 4 0.852058E+02 5
0 0.916249E+02 4 0.795299E+02 5
0 0.962872E+02 4 0.797326E+02 5   Data
0 0.986522E+02 4 0.825705E+02 5
0 0.100612E+03 4 0.808137E+02 5
0 0.108382E+03 4 0.800705E+02 5
0 0.110815E+03 4 0.856112E+02 5
0 0.118045E+03 4 0.824354E+02 5
0 0.119937E+03 4 0.858139E+02 5
0 0.132775E+03 4 0.784488E+02 5
0 0.134937E+03 4 0.862867E+02 5
0 0.145951E+03 4 0.750703E+02 5
0 0.155276E+03 4 0.724350E+02 5
0 0.191493E+03 4 0.741243E+02 5
0 0.193318E+03 4 0.733810E+02 5
0 0.195345E+03 4 0.863545E+02 5
0 0.199588E+03 4 0.767595E+02 5
0 0.213521E+03 4 0.712188E+02 5
0 0.250550E+03 4 0.716918E+02 5
0 0.257780E+03 4 0.686511E+02 5
0 0.263996E+03 4 0.680430E+02 5   End of frame I
0  1 6
0 0.698674E+02 4 0.192575E+02 5   } Frame II
0 0.706107E+02 4 0.240211E+03 5   } Co-ordinates
0 0.221765E+03 4 0.239198E+03 5   }
0 0.221224E+03 4 0.181763E+02 5   }
0  9 6
0 0.712188E+02 4 0.631780E+02 5
0 0.783812E+02 4 0.624347E+02 5
0 0.841922E+02 4 0.634482E+02 5
0 0.876383E+02 4 0.664889E+02 5
0 0.907465E+02 4 0.702728E+02 5
0 0.935845E+02 4 0.671646E+02 5
0 0.977062E+02 4 0.668267E+02 5
0 0.997533E+02 4 0.679403E+02 5
0 0.104053E+03 4 0.676376E+02 5
0 0.106220E+03 4 0.718269E+02 5
```

```
0 0.136964E+03 4 0.710836E+02 5
0 0.139127E+03 4 0.744621E+02 5
0 0.141694E+03 4 0.714891E+02 5
0 0.149127E+03 4 0.692592E+02 5
0 0.151357E+03 4 0.785839E+02 5
0 0.153181E+03 4 0.728405E+02 5
0 0.155614E+03 4 0.777731E+02 5
0 0.160209E+03 4 0.795299E+02 5
0 0.163452E+03 4 0.758811E+02 5
0 0.165547E+03 4 0.799893E+02 5
0 0.167033E+03 4 0.757460E+02 5
0 0.168790E+03 4 0.794623E+02 5
0 0.171966E+03 4 0.766919E+02 5
0 0.175750E+03 4 0.924358E+02 5
0 0.179263E+03 4 0.862867E+02 5
0 0.180615E+03 4 0.103247E+03 5
0 0.182709E+03 4 0.912871E+02 5
0 0.186696E+03 4 0.868950E+02 5
0 0.204534E+03 4 0.789218E+02 5
0 0.208048E+03 4 0.833814E+02 5
0 0.209264E+03 4 0.811516E+02 5
0 0.210751E+03 4 0.901384E+02 5
0 0.213589E+03 4 0.837192E+02 5
0 0.217711E+03 4 0.808137E+02 5
0 0.220481E+03 4 0.797326E+02 5   End of
0  2 6                            Frame II
0 0.475017E+02 4 0.257442E+02 5   } Frame III
0 0.484477E+02 4 0.245955E+03 5   } Co-ordinates
0 0.784488E+02 4 0.246698E+03 5   }
0 0.780434E+02 4 0.258793E+02 5   }
0  9 6
0 0.489883E+02 4 0.872329E+02 5
0 0.508802E+02 4 0.896654E+02 5
0 0.522992E+02 4 0.878410E+02 5
0 0.535154E+02 4 0.991252E+02 5
0 0.547317E+02 4 0.931790E+02 5
0 0.574345E+02 4 0.128451E+03 5
0 0.599346E+02 4 0.171560E+03 5
0 0.625698E+02 4 0.154533E+03 5
0 0.681781E+02 4 0.201629E+03 5
0 0.702052E+02 4 0.191358E+03 5
0 0.733134E+02 4 0.195885E+03 5
0 0.771649E+02 4 0.197102E+03 5
0  3 6   — End of frame III
0 0 6    — Trip No. φ5φ
0 5 6
0 0 6
0 0.147303E+02 4 0.219603E+02 5
0 0.151357E+02 4 0.249401E+03 5
0 0.257644E+03 4 0.248860E+03 5
0 0.257374E+03 4 0.222305E+02 5
0  9 6
0 0.156762E+02 4 0.177912E+03 5
0 0.227711E+02 4 0.156357E+03 5
0 0.314201E+02 4 0.143451E+03 5
0 0.339877E+02 4 0.145411E+03 5
0 0.346634E+02 4 0.171695E+03 5
0 0.367581E+02 4 0.157776E+03 5
0 0.400014E+02 4 0.151288E+03 5
```

```
0 0.505424E+02 4 0.142978E+03 5
0 0.550696E+02 4 0.140883E+03 5
0 0.566912E+02 4 0.143721E+03 5
0 0.572994E+02 4 0.150478E+03 5
0 0.600022E+02 4 0.151424E+03 5
0 0.615563E+02 4 0.148249E+03 5
0 0.631104E+02 4 0.179263E+03 5
0 0.646645E+02 4 0.172777E+03 5
0 0.705431E+02 4 0.230616E+03 5
0 0.745431E+02 4 0.330616E+03 5
0 0.110477E+03 4 0.229265E+03 5
0 0.119396E+03 4 0.200615E+03 5
0 0.121153E+03 4 0.204872E+03 5
0 0.123721E+03 4 0.196223E+03 5
0 0.125748E+03 4 0.206089E+03 5
0 0.128788E+03 4 0.194939E+03 5
0 0.129464E+03 4 0.198183E+03 5
0 0.130748E+03 4 0.191966E+03 5
0 0.132032E+03 4 0.202845E+03 5
0 0.136964E+03 4 0.185007E+03 5
0 0.146086E+03 4 0.169195E+03 5
0 0.168317E+03 4 0.149668E+03 5
0 0.193994E+03 4 0.136491E+03 5
0 0.223995E+03 4 0.123315E+03 5
0 0.226022E+03 4 0.126288E+03 5
0 0.229333E+03 4 0.123113E+03 5
0 0.248860E+03 4 0.116423E+03 5
0 0.256766E+03 4 0.112977E+03 5
0  1 6
0 0.388528E+02 4 0.265550E+02 5
0 0.385825E+02 4 0.253455E+03 5
0 0.189264E+03 4 0.253658E+03 5
0 0.190210E+03 4 0.268929E+02 5
0  9 6
0 0.404069E+02 4 0.116626E+03 5
0 0.460827E+02 4 0.114396E+03 5
0 0.472990E+02 4 0.116491E+03 5
0 0.833814E+02 4 0.109328E+03 5
0 0.985171E+02 4 0.101625E+03 5
0 0.102436E+03 4 0.101490E+03 5
0 0.104058E+03 4 0.102774E+03 5
0 0.105950E+03 4 0.102301E+03 5
0 0.107909E+03 4 0.105274E+03 5
0 0.113180E+03 4 0.103450E+03 5
0 0.115815E+03 4 0.106288E+03 5
0 0.117166E+03 4 0.106558E+03 5
0 0.118585E+03 4 0.109328E+03 5
0 0.125815E+03 4 0.105071E+03 5
0 0.135545E+03 4 0.103382E+03 5
0 0.137505E+03 4 0.105071E+03 5
0 0.139194E+03 4 0.103923E+03 5
0 0.142843E+03 4 0.125748E+03 5
0 0.145005E+03 4 0.119058E+03 5
0 0.145681E+03 4 0.132640E+03 5
0 0.147505E+03 4 0.165209E+03 5
0 0.148789E+03 4 0.154127E+03 5
0 0.149465E+03 4 0.168249E+03 5
0 0.153519E+03 4 0.153722E+03 5
0 0.155411E+03 4 0.151625E+03 5
```

Figure 3

Mop Data

is shown in Figure 4. The data for this are shown on the listing as:

```
0  0.418934E+02  4  0.132910E+03  5  Point A
0  0.456098E+02  4  0.142910E+03  5  Point B
0   0 6
0  0.615563E+02  4  0.142910E+03  5  Point C
0   0 6
0  0.635643E+02  4  0.136820E+03  5  Point D
```

Zero "flags" entered via MOP keyboard

The distance 0-P, figure 4 can be measured in mm directly from the chart using a ruler. The co-ordinates of the peak point P can be edited into the data as follows:

Point B time axis co-ordinate = 0.456098E+02
= 0.456098×10^2 mm
= 45.6098 mm

Point P time axis co-ordinate = 45.6098 + 6.0 = 51.6098 mm
= 0.516098×10^2 mm
= 0.516098E+02

Point B height axis co-ordinate = 0.142910E+03
= 0.142910×10^3 mm
= 142.910 mm

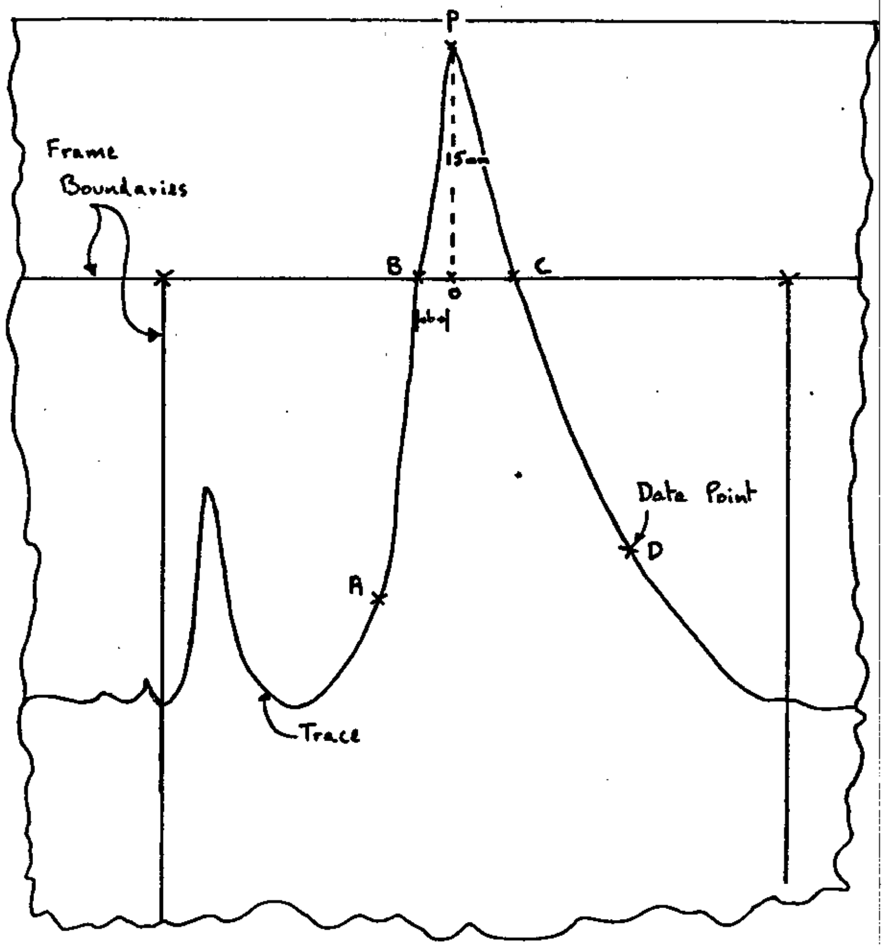
Point P height axis co-ordinate = 142.910 + 15.0 = 157.910 mm
= 0.157910×10^3 mm
= 0.157910E+03

The format of the co-ordinates for the peak point has to conform with the original data so that the processing programs work. The line of data would be edited into the file as: 0 0.516098E+02 4 0.157910E+03 in sequence following the line corresponding to the co-ordinates for point B. The zero "flags" have both to be deleted.

4.2 Frame Squaring and Conversion to Continuous Height/Time Record

Due to the operational inaccuracies in drawing the frames and placing the digitiser pen on the points, the chart frames

Figure 4 Storm Peak



O - P = 15 mm
O - B = 6 mm

are never exactly square. The program MIKE8.BAS, written by G Radford at Bangor, has been utilised to square the frames and then to convert the data to a continuous series of X:Y co-ordinates (in mm) representing each point digitised from the chart records. For a file containing several consecutive weeks data, the time axis (x axis) begins with the first digitised point within frame one of the first week. The x axis co-ordinate values are then a continuous series of incrementing digits extending over the complete time span of the charts. This is illustrated for two weeks data in one file in Figure 5.

The squaring program MIKE8.BAS will process a data file until an error is found or the end of the file is reached. On the completion of each frame an asterisk will be displayed at the terminal. If an error is encountered the program stops automatically. One of a limited number of error messages will be displayed along with co-ordinates in error. The error messages are largely self explanatory and are shown underlined in the program listing in Appendix 2. The frame containing the error can be located on a listing of the file by counting the asterisks printed or displayed at the terminal. MIKE8.BAS appends the letter 'O' to the first part of the file name of the processed file. In order to do this the full file name, including the ".DAT" extension, has to be specified when the program is run.

4.3 Record Continuity

The continuity of the data obtained from MIKE8.BAS can be

Figure 5

Co-ordinate Data from MIKE8.BAS

Trip No.	Time Co-ord	Height Co-ord
49	1.66406	42.6055
49	5.66372	42.7183
49	8.07072	197.227
49	9.95132	140.629
49	9.47142	134.331
49	10.2488	141.433
49	12.9601	104.542
49	15.0949	95.6487
49	23.4478	79.0752
49	36.4797	69.4167
49	45.8927	65.0468
49	47.6955	64.1525
49	49.3353	67.3579
49	56.4089	59.9803
49	68.727	54.3176
49	73.4264	54.5346
49	75.8171	57.4422
49	77.7228	55.6483
49	85.525	54.9732
49	87.9075	60.4808
49	95.1176	57.3038
49	97.0068	60.7099
49	109.93	53.351
49	112.005	61.2577
49	123.141	50.0932
49	132.449	47.4229
49	168.644	49.2384
49	170.446	48.5441
49	172.405	61.5504
49	175.735	51.961
49	190.653	46.4086
49	227.751	47.027
49	234.961	44.0499
49	241.163	43.3697
49	244.148	43.9067
49	251.352	43.1481
49	257.147	44.1814
49	260.529	47.3008
49	263.607	51.1185
49	266.525	48.0352
49	270.627	47.6588
49	272.621	48.6702
49	277.022	48.4955
49	279.098	52.7075
49	305.121	48.8568
49	307.05	61.1681
49	309.902	52.1843
49	311.982	55.5963
49	314.599	52.6112
49	322.012	50.4538
49	324.258	59.7668
49	326.092	53.9772
49	328.463	58.9909
49	333.053	60.7173
49	336.374	57.1363
49	338.356	60.2477
49	339.875	56.9564
49	341.653	60.7667
49	344.369	57.9951
49	352.114	67.6268
49	353.317	84.534
49	355.485	72.6462
49	359.51	68.2693
49	377.356	60.3716
49	380.83	64.8916
49	382.142	62.6991
49	383.591	71.6075
49	386.429	65.2237
49	390.545	62.3473
49	393.351	61.2634
49	396.181	61.4925
49	398.092	63.7838
49	399.483	62.0775
49	400.735	73.3719
49	401.908	67.4664
49	404.769	102.754
49	407.466	145.842
49	410.087	128.73
49	415.902	175.804
49	417.856	165.595
49	420.976	170.081
49	424.882	171.263
50	425.927	155.9
50	433.023	134.399
50	441.621	121.497
50	444.221	123.397
50	444.926	149.697
50	447.023	135.796
50	450.222	129.296
50	452.822	128.295
50	460.721	120.994
50	465.32	118.893
50	466.921	121.693
50	467.522	128.493
50	470.222	129.392
50	471.822	126.192
50	473.327	157.292
50	474.926	150.791
50	480.736	208.59
50	484.753	308.59
50	520.735	207.284
50	529.63	178.582
50	531.431	182.882
50	533.93	174.181
50	535.931	184.081
50	539.03	172.88
50	539.73	176.18
50	540.929	169.98
50	542.231	180.78
50	547.228	162.979
50	556.325	147.178
50	578.522	127.674
50	604.22	114.469
50	634.217	101.264
50	636.218	104.264
50	639.517	101.063
50	659.116	94.36
50	667.016	90.9586
50	674.992	87.784
50	676.197	89.8814
50	712.281	82.6022
50	727.364	74.8691
50	731.264	74.7606
50	732.967	76.0569
50	734.866	75.5527
50	736.772	78.5485
50	742.068	76.7369
50	744.675	79.5312
50	746.075	79.8281
50	747.481	82.525
50	754.672	78.3093
50	754.368	76.588
50	766.372	78.2836
50	768.069	77.0799
50	771.717	98.8719
50	773.903	92.2671
50	774.632	105.766
50	776.504	138.362
50	777.779	127.259
50	778.51	141.357
50	782.478	126.848
50	794.374	124.844
50	785.398	135.742
50	787.879	127.137
50	788.691	132.535
50	790.58	127.431
50	791.488	131.129
50	796.462	119.318
50	797.891	132.815
50	799.279	127.012
50	900.386	130.409
50	806.165	120.496
50	807.274	124.694
50	808.767	121.591
50	808.87	123.191
50	818.053	115.27
50	821.76	110.578
50	838.89	103.213
50	843.57	101.068
50	850.043	98.2059

checked using MOPCHK.BAS which looks for records which have time co-ordinates that are out of sequence. This tends to occur on the steeply rising limbs of storms and is again related to errors in misplacing the digitiser pen. The program processes the complete data file and displays erroneous co-ordinates along with their respective line numbers. The files can then be edited as required.

4.4 Conversion of co-ordinates to Flow and Time

This is achieved using the program VFLO1.BAS. The time axis can be converted from mm to time in seconds simply, as 15 mm = 6 hours on the weekly charts.

Stage heights can be converted to flow using the experimentally derived relationship of

$$\log_{10} H = 0.4002876 \times \log_{10} Q + 0.74429 \quad (1)$$

where H = head of water (= stage height - datum height) cm
Q = flow l/s

Alternatively, and to cope with sharp rises in stage height flow may also be computed using an integration of the hydrograph curve derived by D Moss at Bangor. The conditions set in the program for the choice of formula are for two consecutive values of head, hi and h_2:

If $(h_2 - hi) \leqslant 0.2\ ((h_2 + h)/2)$ then equation 1 above is used
If $(h_2 - hi) > 0.2\ ((h_2 + hi)/2)$ then the integration technique is selected.

These limits were selected on theoretical grounds during the derivation of the hydrograph integral.

Flow data from VFLO1.BAS is formatted as shown in Figure 6. Thus for the first line of data in Figure 6, the total flow was 2983.55 1 for 5759.51 seconds, equivalent to a discharge of 0.52 l/s for a period of about 1.6 hours.

The flow data files are given the same nomenclature as the original digitised data file, except that a ".FLO" extension is used.

i.e.: C4D1.DAT $\xrightarrow{\text{MIKE8}}$ C4D10.DAT $\xrightarrow{\text{VFLO1}}$ C4D1.FLO

4.5 Missing Data

For small catchments of similar size and topography and in close proximity to one another, the discharge patterns measured during the same time period are often closely related (M. Newson, pers. comm. 1981). This observation has been used as the basis for deriving values for missing data in the weir hydrograph records. Values of instantaneous discharge for two weirs recorded at approximately the same time (within 4 hours) have been correlated using the program XYPLOT.BAS. Generally, correlations greater than 0.9 have been found for about 50 data points. The regression equation produced has then been used in conjunction with flow data from one weir to generate values for missing data for the other weir. This technique has only been applied, however, to situations where one or at the most three consecutive weeks data have been absent. A simple program, GENFLO.BAS, has been written to perform these computations. The output created by this program is compatible with that from VFLO1.BAS.

4.6 Data summarisation

When the values for missing data have been computed all the flow data files can be merged using the PIP utility, to create one file containing a sequential record of stream flow. This information can be summarised using FLOSTAT.BAS. This program will produce mean, minimum and maximum flows in litres per second for periods between specified week numbers. There is an additional option to create a file containing total weekly flows in litres which can be displayed graphically using locally available plotting programs.

5 REFERENCES

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The assistance given by the following staff at Bangor is gratefully acknowleged. Mrs P Benham for preparing Appendix 1 and Mr G Radford and Dr D Moss for computer programs and mathematical advice respectively.

Trip No.	Discharge (l)	Time period (s)
49	2983.55	5759.51
49	29874.3	3466.08
49	20438.4	1268.06
49	7215.72	748.943
49	10864.1	1119.43
49	29060.7	3904.27
49	13741.9	3074.11
49	37336.3	12028.2
49	38795.8	18764.5
49	21873.9	13556.2
49	3791.17	2596.03
49	3714.46	2433.31
49	14244.4	10114
49	19073.9	17738.1
49	6441.39	6767.14
49	3516.77	3442.6
49	2873.49	2744.2
49	11133.4	11235.2
49	3782.93	3430.8
49	12034.2	10382.6
49	3168.55	2720.44
49	19906.5	18609.4
49	3234.77	2988.02
49	16153.5	16035.8
49	9693.18	13403.5
49	36872.9	52120.8
49	1889.4	2594.88
49	2786.27	2920.97
49	5067.9	4795.17
49	15877.2	21481.9
49	34720.7	53421.1
49	6330.45	10382.4
49	4915.5	8930.87
49	2356.15	4298.41
49	5650.32	10373.8
49	4581.1	8344.78
49	3002.56	4870.09
49	3280.05	4432.31
49	3167.85	4201.94
49	4075.12	5906.84
49	2013.93	2871.34
49	4542.12	6337.47
49	2371.91	2989.44
49	29998.1	37473.1
49	2736.86	2777.78
49	4325.28	4106.88
49	2781.31	2995.22
49	3534.1	3768.5
49	8864.28	10674.7
49	3175.97	3234.22
49	2805.45	2640.94
49	3565.45	3414.25
49	7977.43	6609.59
49	5551.17	4782.28
49	3280.06	2854.06
49	2504.25	2187.38
49	2963.74	2560.31
49	5478.53	4631.03
49	9255.91	5342.39
49	3836.09	1732.34
49	7439.72	3121.91
49	10513.9	5796
49	37125.1	25698.3
49	6762.24	5002.56
49	2674.08	1889.31
49	3356.92	2086.5
49	6885.74	4085.31
49	8387.71	5929.44
49	5283.8	4040.69
49	5237.34	4075.19
49	3735.61	2751.81
49	2750.95	2003.06
49	2962.65	1802.88
49	3059.86	1689.13
49	12301.5	4119.81
49	29633.2	3883.69
49	36235.1	3774.25
49	105679	8373.62
49	46548.9	2813.75
49	71252.8	4492.81
49	93012.8	5624.63
50	22381	1504.75
50	112746	10218.3
50	99686.8	12381.1
50	27010.8	3744
50	9616.47	1015.25
50	31957	3019.63
50	40510	4606.63
50	30646.1	3744
50	85789	11374.5
50	45375.1	6622.56
50	15911.6	2305.5
50	6585.67	965.375
50	31916.2	3888.06
50	18494.2	2304
50	22703.4	2167.19
50	29473.9	2302.56
50	159880	8366.38
50	276363	5784.5
50	2.40390E+06	51814.1
50	287713	12908.8
50	49484.3	2593.5
50	66591.8	3598.56
50	53769.7	2881.44
50	82520.1	4462.5
50	17627.3	1008.06
50	29567.5	1726.5
50	33185	1874.88
50	121107	7195.69
50	170517	13099.7
50	307653	31963.7
50	259543	37005.1
50	227038	43195.7
50	13418.2	2881.44
50	22068.4	4750.56
50	115875	28222.6
50	40905.9	11376
50	11128.6	3284.69
50	5615.71	1735.25
50	156174	51960.9
50	51998.9	21719.5
50	11834.8	5616.06
50	5271.02	2452.38
50	5954.82	2734.5
50	6225.26	2744.63
50	17631.5	7626.25
50	8817.22	3754.13
50	4972.07	2015.88
50	5231.63	2024.75
50	26134.8	10355
50	32078.9	13962.3
50	6627.4	2985.75
50	5656.94	2443.75
50	16752.4	5253.13
50	12227.7	3147.75
50	4455.25	1049.75
50	19511	2695.75
50	16226.1	1836
50	9567.1	1052.63
50	51734	5713.88
50	21091.6	2730.25
50	12423	1474.5
50	30767.2	3572.75
50	9765.09	1169.25
50	22781.7	2720.13
50	10803.3	1307.5
50	54651.1	7162.62
50	15966.1	2057.75
50	16717.6	1998.75
50	13027	1594.13
50	63785.8	8321.75
50	11555.4	1596.88
50	15731.1	2149.88
50	1069.22	148.375
50	89262.7	13223.5
50	31459.9	5338.13
50	126756	24667.1
50	30909.8	6739.25
50	40181.9	9321.12

Figure 6 Flow Data from VFLO1.BAS

Additionally, the assistance rendered, at many stages during the work, by Dr M Newson of the Institute of Hydrology at Plynlimon, is gratefully acknowledged.

Appendix 1

Instructions for MOP Users

1. VDU

Check switch is in VDU position on aluminium base.

Log in normally:-

Type HEL HORNUNG

Password Mike

then MOP W2D1.DAT = TI:
(W2D1.DAT = file name)

2. Set up 'MOP-2':-

Press 'CLEAR' until all zero's are displayed

" 'SET'

" 'SEND'

" 'X, Y CO-ORD'

" 'ENTER'

" 'X, Y CO-ORD'

" 'DISCRIM'

* Switch to MOP position on aluminium base

Insert trip number, e.g. 036, 104, etc. The trip number will not be displayed. Plot corner co-ordinates of frame 1 with pen IN THE ORDER: BL, TL, TR, BR

Press '9' (on MOP terminal)

Plot 'crosses' on frame 1

Press '1'

" corner co-ords of frame 2

Press '9'

Plot 'crosses' on frame 2

Press '2'

Plot corner co-ords of frame 3

Press '9'

Plot 'crosses' on frame 3

Press '3'

Insert next trip number and repeat the above operation with the corresponding chart.

NB HIGH PEAKS

Plot highest point within frame and then press '0'.

Plot second point, followed by '0', e.g.

3 At the end of the file, switch back to VDU position

Then 'CONTROL Z' to CLOSE file

4 To RE-OPEN file:-

Type MOP W2D1.DAT = TI:/AP
(W2D1.DAT = file name)

5 For print-out:-

Type BAS (CR)
OLD (CR)

Old file name DLO: [1,54] COLUMN,BAS

Number of columns to be output 4

When READY, type RUN

To get back into 'MCR', type BYE

6 Alternatively, for single column print-out type PIP W2D1.DAT/SP

file name (W2D1.DAT)

NB Remember to log off by typing BYE, when day's files are closed.

Appendix 2

MIKE8.BAS Squaring Program

Notes on running the program (see Fig. 7)

i) In response to "File name"? prompt, it is necessary to enter full file name, i.e. including ".DAT" extension.

ii) In response to "Registration terminators (1) or not (2)"? enter 1 as the MOP data has terminators at the ends of the frame co-ordinates and the digitised data.

iii) Error messages

a) "error in co-ordinate pair ....". This is fairly self explanatory, often due to a misplaced character.

b) "Syntax Error in frame terminator". This again is self explanatory and may again be due to a misplaced character.

c) "Frame not square; opposite sides unequal". The program attempts to square correct frames that are not square. However it can only operate within certain defined limits of accuracy in the original data. This error message suggests a gross mistake in one or more of the frame co-ordinates.

d) "Frame not square; angles inconsistent". Again the program can only operate within certain limits of accuracy in the original data. As above, this message implies that there is a gross error in one or more of the frame co-ordinates. The angle subtended by the sides of the frames are too far from 90^{o} to be corrected by the program.

Note on other processing programs.

The processing programs MOPCHK.BAS, VFLO1.BAS and FLOSTAT.BAS are all relatively simple programs and therefore have not been listed. On the Public Disc of the Bangor PDP-11 they are stored under UIC DLI: [100, 15]. They are also maintained as copies on DEC tape and paper tape.

XYPLOT.BAS and COLUMN.BAS are locally available general purpose programs for plotting and printing data files respectively. They are retained on the System Disc of the PDP-11 under DLØ: [1ØØ,54]. See also Bangor Software Notices numbers 8A and 12.

Fig 7 MIKE8.BAS Program Listing

```
10 REM...PROGRAM TO HANDLE MAP REGISTRATION FROM MOP-2 DIGITISER
20 REM...MIKE6.BAS        G.L.RADFORD       JAN-1980
30 REM...THE PROGRAM REQUIRES INPUT FROM A FILE CREATED UNDER PIP
40 GOSUB 170 \ REM...INITIALISE
50 GOSUB 60 \ GO TO 590
59 REM    TO HANDLE REGISTRATION
60 E=0 \ T9=0 \ FOR I=1 TO 3 \ IF END #1 THEN 810 \ LINPUT #1:A$
62 T9=T9*10+VAL(SEG$(A$,4,4))
63 NEXT I
65 E=0 \ PRINT "*"; \ FOR I=1 TO 4 \ LINPUT #1:A$ \ GOSUB 300 \ IF E=0 THEN 80
70 PRINT "Error in coordinate pair:    ";A$ \ STOP
80 NEXT I \ S(1)=Y(2)-Y(1) \ S(2)=X(3)-X(2) \ S(3)=Y(3)-Y(4) \ S(4)=X(4)-X(1)
85 H9=H8 \ H8=S(4)
90 X0=X(1) \ X9=X(4) \ Y0=Y(1)
100 IF ABS(S(3)-S(1))<5 THEN 120
110 PRINT "Frame not square; opposite sides unequal" \ STOP
120 IF ABS(S(4)-S(2))>=5 THEN 110
130 GOSUB 470 \ REM...COMPUTE ANGLES
140 I=1 \ IF F2=1 THEN LINPUT #1:A$
141 RETURN
150 REM*********************************************************
160 REM...TO INITIALISE
170 M1$="Frame not square; angles inconsistent:    "
180 DEF FNA(X)=X1*COS(A2)-Y1*SIN(A2)
190 DEF FNB(Y)=X1*SIN(A2)+Y1*COS(A2)
200 DIM A(4),X(4),Y(4)
210 A0=4 \ L0=4 \ REM...MATCHED LIMITS FOR ANGLE AND LENGTH
220 S1$="0 0." \ A1=0 \ S=0 \ S1=0 \ S2=0
230 PRINT "File name    "; \ LINPUT X$ \ P=POS(X$,".",1)
240 IF P=0 THEN 230
250 OPEN X$ FOR INPUT AS FILE #1 \ X$=SEG$(X$,1,P-1)&"O"&SEG$(X$,P,200)
260 OPEN X$ FOR OUTPUT AS FILE #2
265 PRINT "Registration terminators(1) or not (2)   "; \ INPUT F2
270 RETURN
280 REM*********************************************************
290 REM...TO CHECK A COORD LINE,SALVAGE AND PARSE
300 B$=A$
320 P=POS(B$,"+",1) \ IF P=12 THEN 360
330 IF P<8 THEN E=1 \ RETURN
340 IF P>12 THEN B$=SEG$(B$,2,200) \ GO TO 320
350 B$=SEG$(S1$,1,12-P)&B$
360 IF SEG$(B$,1,4)<>S1$ THEN 390
370 IF SEG$(B$,15,19)<>" 4 0." THEN 390
380 IF SEG$(B$,30,31)=" 5" THEN A$=B$ \ GO TO 410
390 E=1 \ RETURN
```

MIKE8.BAS Program Listing - continued

```
400 REM...PARSE A CORRECT LINE.   COORDS ROUNDED TO 1 PLACE
410 X(I)=VAL(SEG$(A$,3,14))*10 \ X(I)=(INT(X(I)+.5))/10
420 Y(I)=VAL(SEG$(A$,18,29))*10 \ Y(I)=(INT(Y(I)+.5))/10
430 RETURN
440 REM**********************************************************
450 REM...TO COMPUTE ANGLES IN DEGREES
460 REM...CALCULATE TANGENT OF ANGLE
470 A(1)=X(2)-X(1) \ A(2)=Y(2)-Y(3) \ A(3)=X(3)-X(4) \ A(4)=Y(1)-Y(4)
480 REM...CONVERT TO ANGLES IN DEGREES
490 FOR J=1 TO 4 \ B(J)=ATN(A(J)/S(J))*180/PI
500 IF J=1 THEN 520 \ IF ABS(B(J)-B(J-1))<=A0 THEN 520
510 PRINT M1$;B(J);B(J-1) \ STOP
520 A1=A1+B(J) \ NEXT J
530 IF ABS(B(4)-B(1))<=A0 THEN 550
540 PRINT M1$;B(4);B(1) \ STOP
550 A1=A1/4
560 A2=A1*PI/180
570 RETURN
580 REM**********************************************************
590 REM
600 IF END #1 THEN 810
610 LINPUT #1:A$ \ IF POS(A$,"+",1)>0 THEN 650
620 IF SEG$(A$,1,3)="0  " THEN 640 \ IF SEG$(A$,6,6)="6" THEN 640
630 IF LEN(A$)=1 THEN 810 \ PRINT "SYNTAX ERROR IN FRAME TERMINATOR:  ";A$ \ STOP
640 T1=VAL(SEG$(A$,4,4)) \ IF T1=3 THEN  GOSUB 60 \ GO TO 645
642 GOSUB 65
645 O2=O2+H9 \ GO TO 600
650 GOSUB 300 \ IF E=0 THEN 670
660 PRINT "ERROR IN COORDINATE PAIR:  ";A$ \ STOP
670 X1=X(1) \ Y1=Y(1)
680 REM...TRANSFORM W.R.T. FRAME ORIGIN
690 X1=X1-X0 \ Y1=Y1-Y0
700 GOSUB 790
710 IF X3<0 THEN X3=0
720 PRINT #2:T9;",";X3+O2;",";Y3
730 GO TO 600
750 STOP
760 REM**********************************************************
770 REM
780 REM...TO ROTATE AXES
790 X3=FNA(X1) \ Y3=FNB(Y1)
800 RETURN
810 END
```

Appendix 3

It was mentioned earlier that the flow data have been used in conjunction with stream water chemistry to calculate solute losses from experimental catchments. For completeness, therefore, the simple flow chart in Figure 8 has been included to outline the way in which the loss of material in solution may be computed for a gauged catchment.

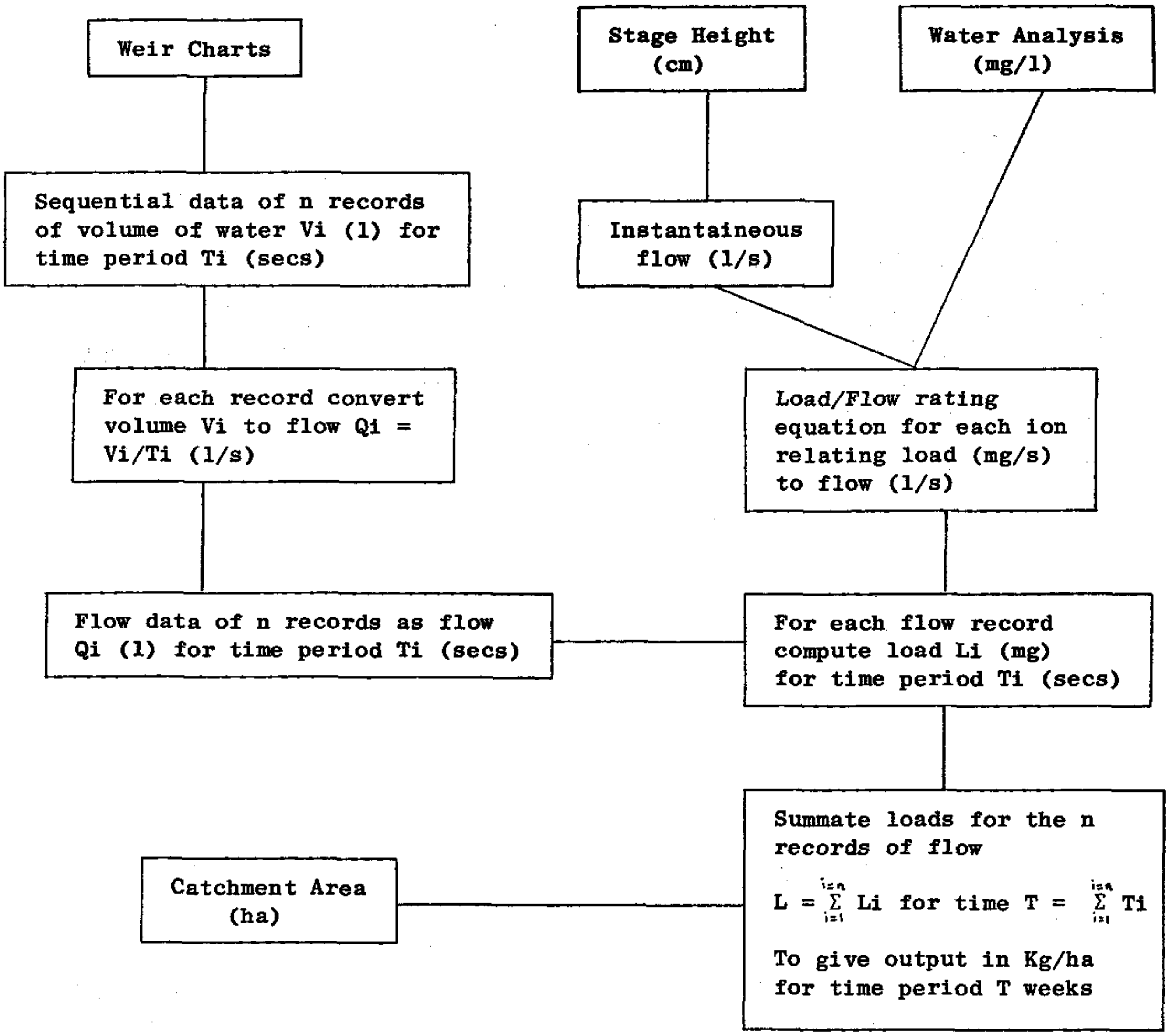

Figure 8

Flow Chart Describing Stages in Processing Stream Flow and Chemical Data for Computing Solute Losses from a Gauged Catchment