SOUTHLAND REGIONAL COUNCIL

LOWER WAIAU RIVER

FLOW ATTENUATION
AND
TIMES OF TRAVEL
(Part A)

and

FLOW RECESSION PROFILE
AND
TIMES OF TRAVEL
(Part B)

D.C. RIDDELL

June 1994

A report to the Southland Regional Council's Waiau River Working Party

EXECUTIVE SUMMARY of PARTS A & B

1. In a flood Manapouri Lake Control (MLC) gates are opened progressively in steps as the lake level and/or Mararoa R level increases.

2. As the flood wave progresses downstream from MLC there is no discernible attenuation (or flattening) of the flow hydrograph. Frequently in fact there is further augmentation of Lower Waiau River flows from the lower tributaries.

3. Although there is no attenuation the "step effect" does become less pronounced with distance downstream but nevertheless is still very evident, even at Tuatapere.

4. When MLC gate openings are adjusted, the new flow immediately downstream of the gates takes about 30 minutes to stabilise.

5. When MLC gate openings are increased, the flow at Sunnyside can start increasing as little as 2 hours later and at Tuatapere as little as 7 hours later.

6. River flow at Sunnyside stabilises after a maximum of five hours, and at Tuatapere after a maximum of 11 hours, following an increase in MLC outflow.

7. As a flood recedes and lake level and/or Mararoa River level drops the MLC gates are progressively closed in steps.

8. As with flow increases, flow decreases are also noticeably stepped all down the lower Waiau River.

9. As with increases, flow reductions can also be noticed after as little as two hours at Sunnyside, and seven hours at Tuatapere, following a MLC outflow reduction.

10. The minimum time for reduced downstream flow to stabilise is 4½ hours at Sunnyside and 11 hours at Tuatapere.

11. At low flows the lag times are much greater so that when MLC gates are closed completely (outflow reduced to zero) the effect is not apparent at Sunnyside until 5 hours later and Tuatapere 14 hours later.

12. Following on from (11) above, when the gates are closed, the reduced downstream flow does not stabilise at Sunnyside until after 11 hours has elapsed, and at Tuatapere until after 26 hours has elapsed.

PART A FLOW ATTENUATION AND TIMES OF TRAVEL

1. Objective

To examine the rising flow profile, flow attenuation and times of travel of water released from the Manapouri Lake Control (MLC) structure.

This particular study focuses on the rising limb of flood hydrographs produced by gate opening sequences.

Knowledge of flow attenuation and travel times will enable appropriate manipulation of the control gates to achieve targeted flows in the lower Waiau River.

2. Method

Records were selected of suitable gate opening sequences. Only 10 flood events between 1977 and 1991 were found to be suitable for analysis.

One such spill sequence is shown in Figure 1. Note however that the rate and magnitude of spilling varies from one flood to another.

3. Background

The MLC gates are operated according to a set of rules which are governed by either Manapouri Lake level or Mararoa River flow. These rules state that the gates must be opened in stages as the lake level and/or Mararoa River rises. Conversely the gates are closed in stages as the lake level and/or Mararoa River flow decreases.

Because the gate movements are "incremental" the outflow from the structure is stepped as shown in Figure 1.

4. Analysis

In each spill sequence examined the parameters which were recorded against MLC outflow were: Sunnyside and Tuatapere flows post increase; time from commencement of gate opening until commencement of downstream flow increase; time from cessation of gate opening until stabilisation of the downstream flow increase.

5. Results

Time for the Waiau R at Sunnyside to respond to an increase in MLC outflow varies slightly with the magnitude of MLC outflow (Figure 2). In general the response time varies from 3 to 4½ hours when the gates are first opened, to between 2 and 3 hours at outflows greater than about 300 m^3/s.

The time for increased flows at Sunnyside to stabilise are less dependent upon magnitude of the flow (Figure 3). In general flows at Sunnyside stabilise 3 to 5 hours following an increase in MLC spill.

Time for the Waiau R at Tuatapere to respond to an increase in MLC outflow varies from about 10 hours at low flows down to about 7 hours at higher flows (Figure 4).

The time for increased flows at Tuatapere to stabilise ranges from 10 - 11 hours at low flows down to 8 - 9 hours at higher flows (Figure 5).

Figure 6 shows the flow hydrograph at MLC, Sunnyside and Tuatapere for a sequence of gate openings from a gates closed position up to an outflow release of about 230 m^3/s. In this particular instance when the MLC gates are first opened flow at Sunnyside begins to increase 2½ hours later and at Tuatapere 10½ hours later.

When MLC outflow is increased from 155 m^3/s to 230 m^3/s the river at Sunnyside begins to rise after 2½ hours and at Tuatapere after 8 hours. The increased flows at Sunnyside and Tuatapere stabilise after 4 hours and 10 hours respectively.

6. Flow Attenuation

Figures 1 and 6 being hydrographs of increasing flows show that there is little attenuation (dampening) of flows with downstream progression. The stepped nature of the increased flows is still very evident at Tuatapere although by then the rising limb of the step is more gradual and the top of the step more rounded.

Frequently inflows to the main Waiau R channel from downstream tributaries cause distortions to the downstream hydrographs such as is evident in both Figures 1 and 6.

MLC gates control the outflow up to about 400 - 500 m^3/s after which the gates are fully opened and if the lake level is high enough water may also flow over the weir. In this situation outflow is essentially uncontrolled and similar to a natural lake outlet. Such a flow hydrograph is shown in Figure 7 which is a portion of the 1988 October / November flood hydrograph.

In Figure 7 there is no attenuation of the flood peak and in fact the downstream peaks are augmented by local tributary inflows. This is the case in most Lower Waiau floods and so affects the relative timing of peaks. In this particular case Sunnyside peaks some 2 hours after MLC and Tuatapere some 5 hours after MLC. Frequently the influence of tributary inflows results in downstream peaks occurring before MLC outflow has peaked - particularly in large flood events.

7. Summary

1. There is really no discernible attenuation of spill flows downstream of MLC although the increase in flow becomes less abrupt with distance. Generally the increase in downstream flow corresponds to the incremental increase in MLC outflow.

Nevertheless tributary freshes often augment the spill flows.

2. When MLC gates are opened from fully closed the flow begins to rise at Sunnyside about 4 hours later and at Tuatapere about 10 hours later.

3. When MLC outflow is increased to $300m^3/s$ and greater the increase in flow is noticed at Sunnyside some 3 hours later and at Tuatapere some 7 hours later.

4. Increased spill flows stabilise at Sunnyside 3 to 5 hours, and at Tuatapere 8 to 11 hours after a gate adjustment.

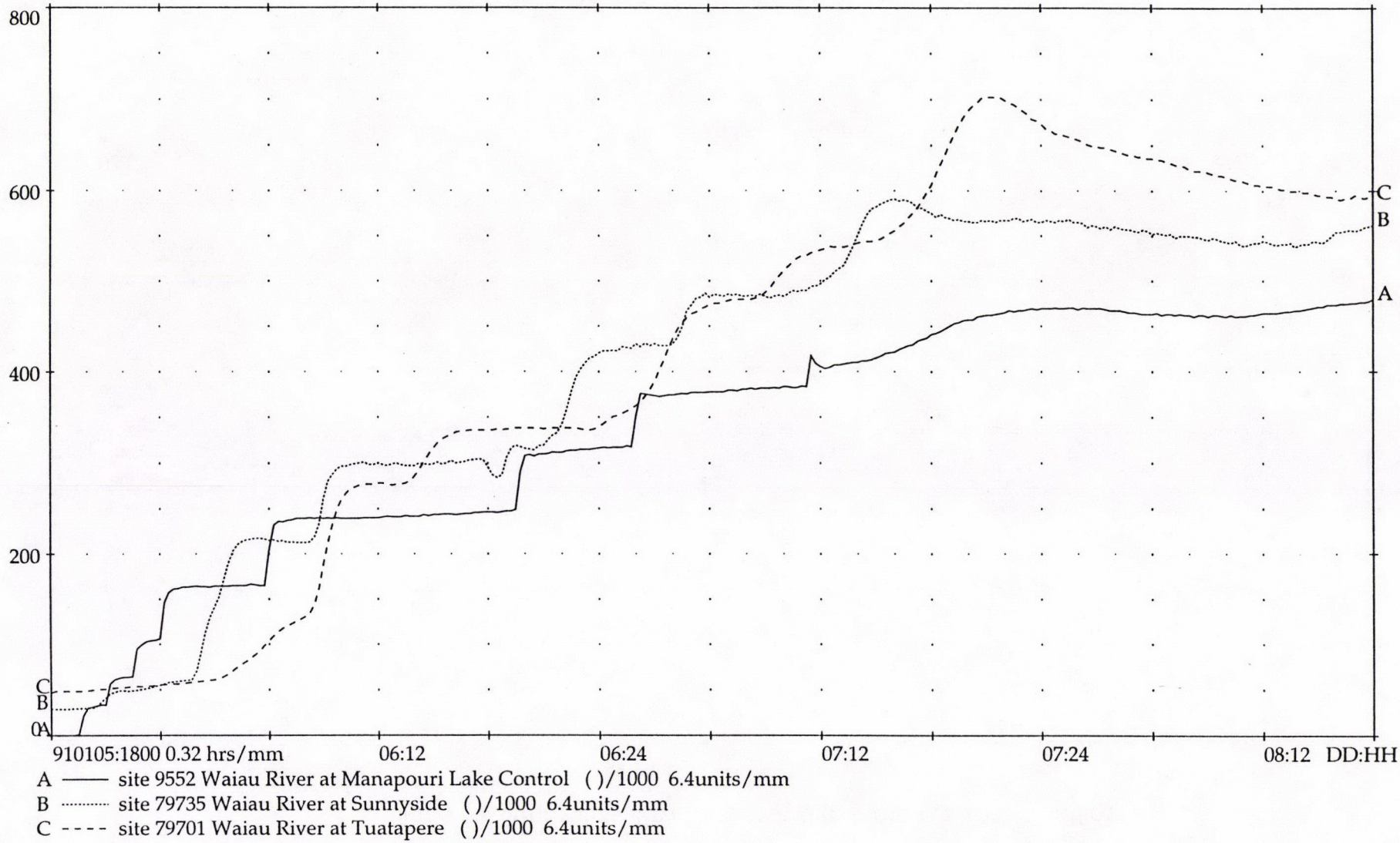

800
600
400
200
0
A
B
C
910105:1800 0.32 hrs/mm
06:12
06:24
07:12
07:24
08:12 DD:HH
A —— site 9552 Waiau River at Manapouri Lake Control ( )/1000 6.4units/mm
B ..... site 79735 Waiau River at Sunnyside ( )/1000 6.4units/mm
C - - - - site 79701 Waiau River at Tuatapere ( )/1000 6.4units/mm

FIGURE 1

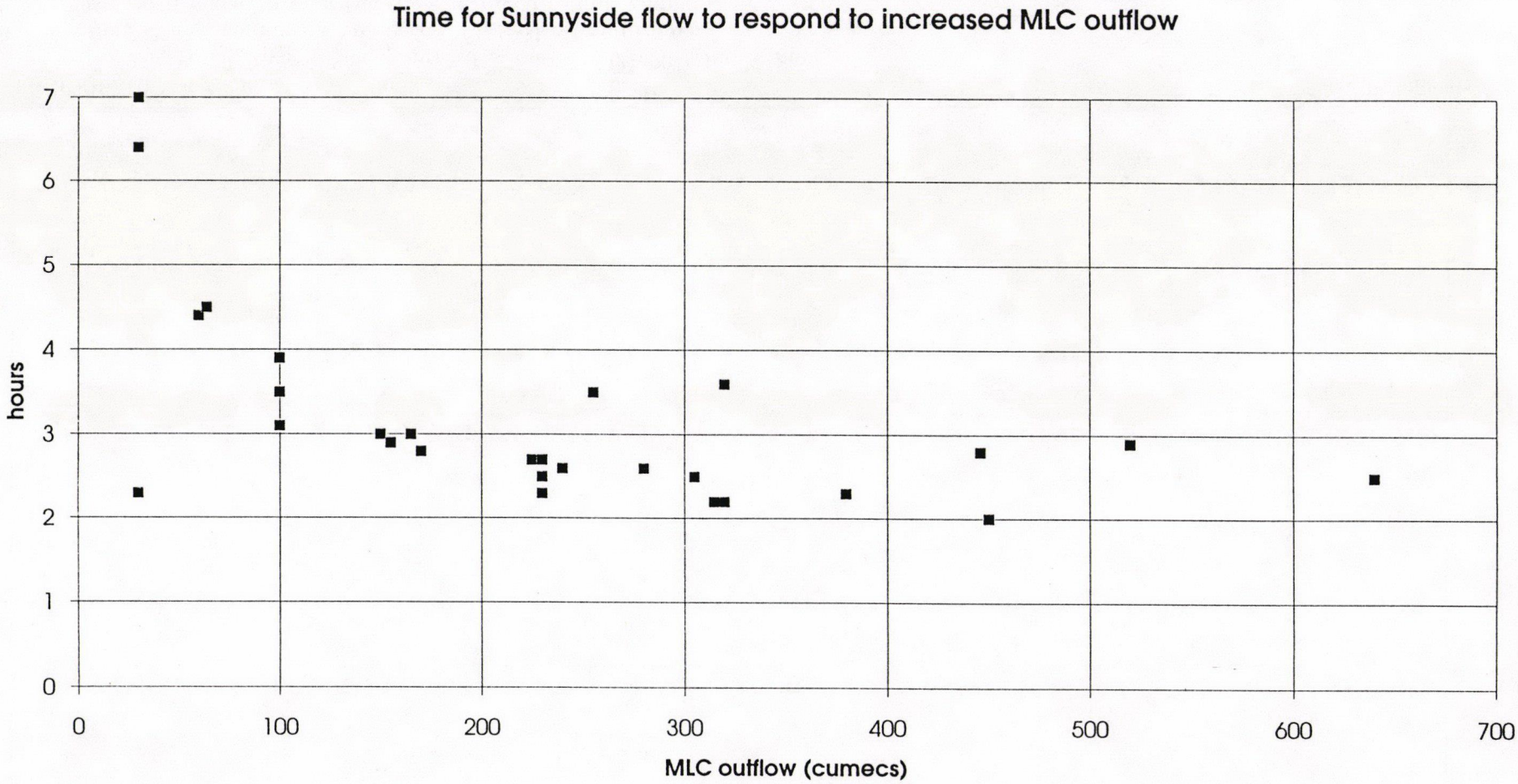

Time for Sunnyside flow to respond to increased MLC outflow
hours
0
1
2
3
4
5
6
7
0
100
200
300
400
500
600
700
MLC outflow (cumecs)

FIGURE 2

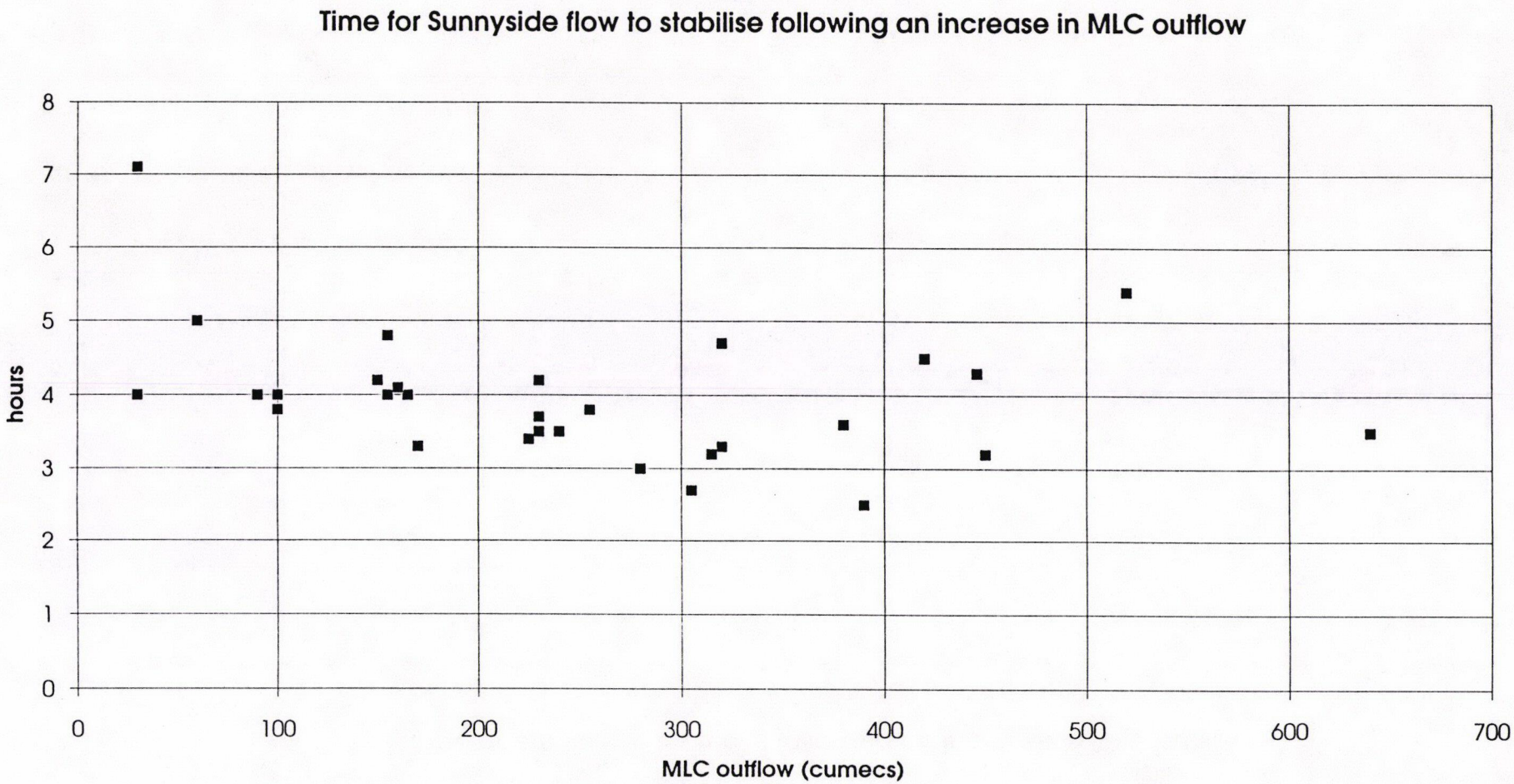

Time for Sunnyside flow to stabilise following an increase in MLC outflow
hours
0
1
2
3
4
5
6
7
8
0
100
200
300
400
500
600
700
MLC outflow (cumecs)

FIGURE 3

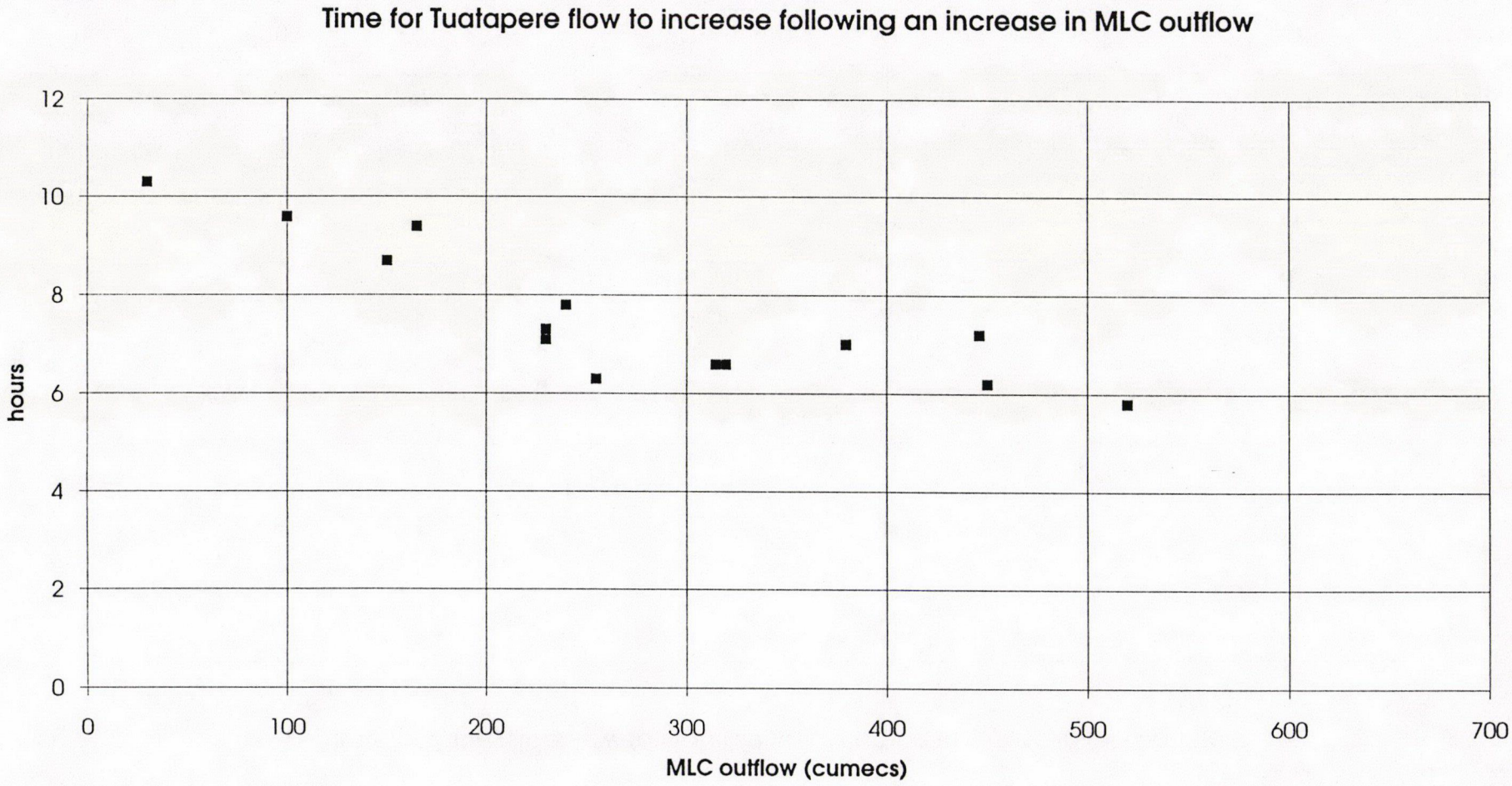

Time for Tuatapere flow to increase following an increase in MLC outflow
hours
12
10
8
6
4
2
0
0
100
200
300
400
500
600
700
MLC outflow (cumecs)

FIGURE 4

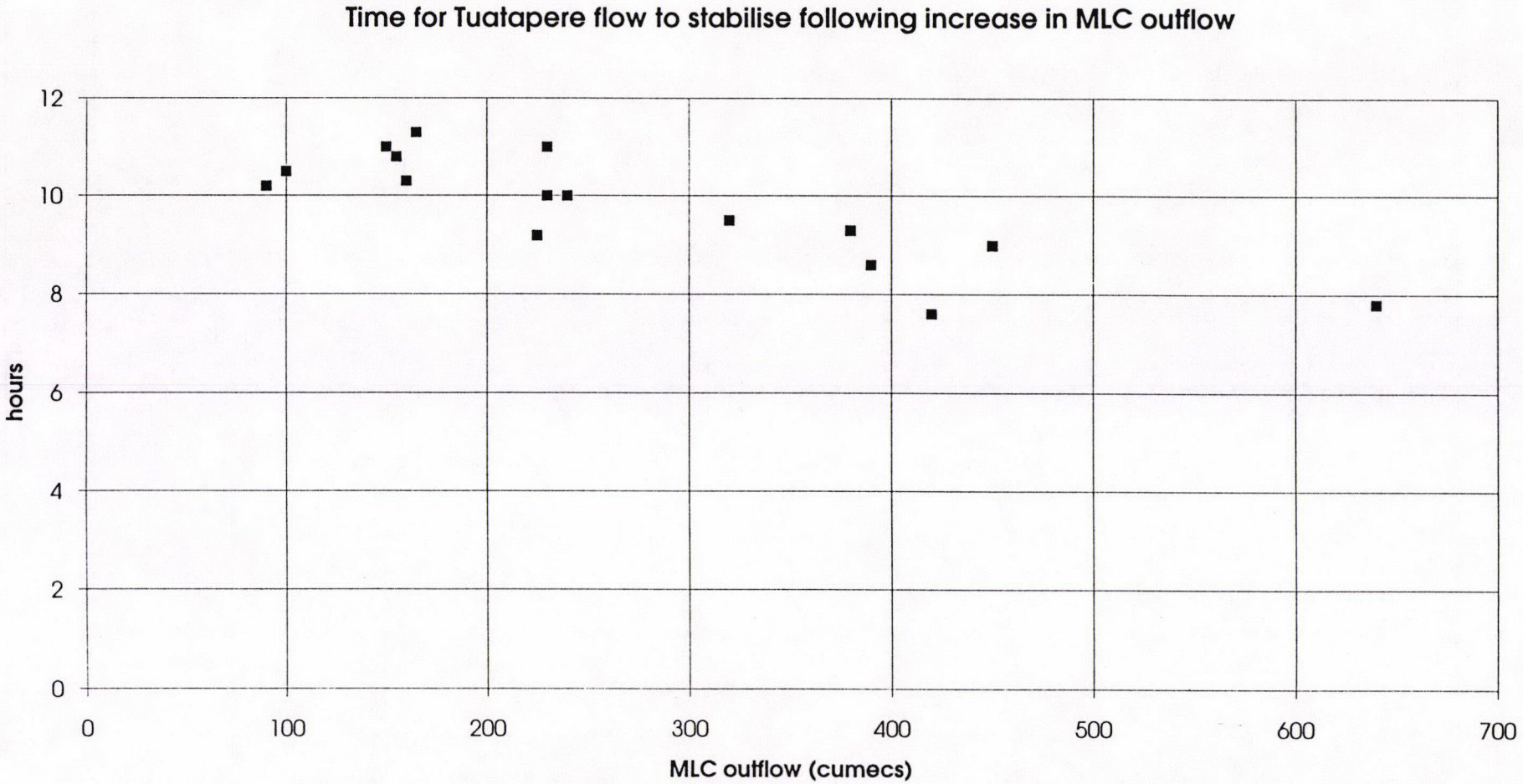
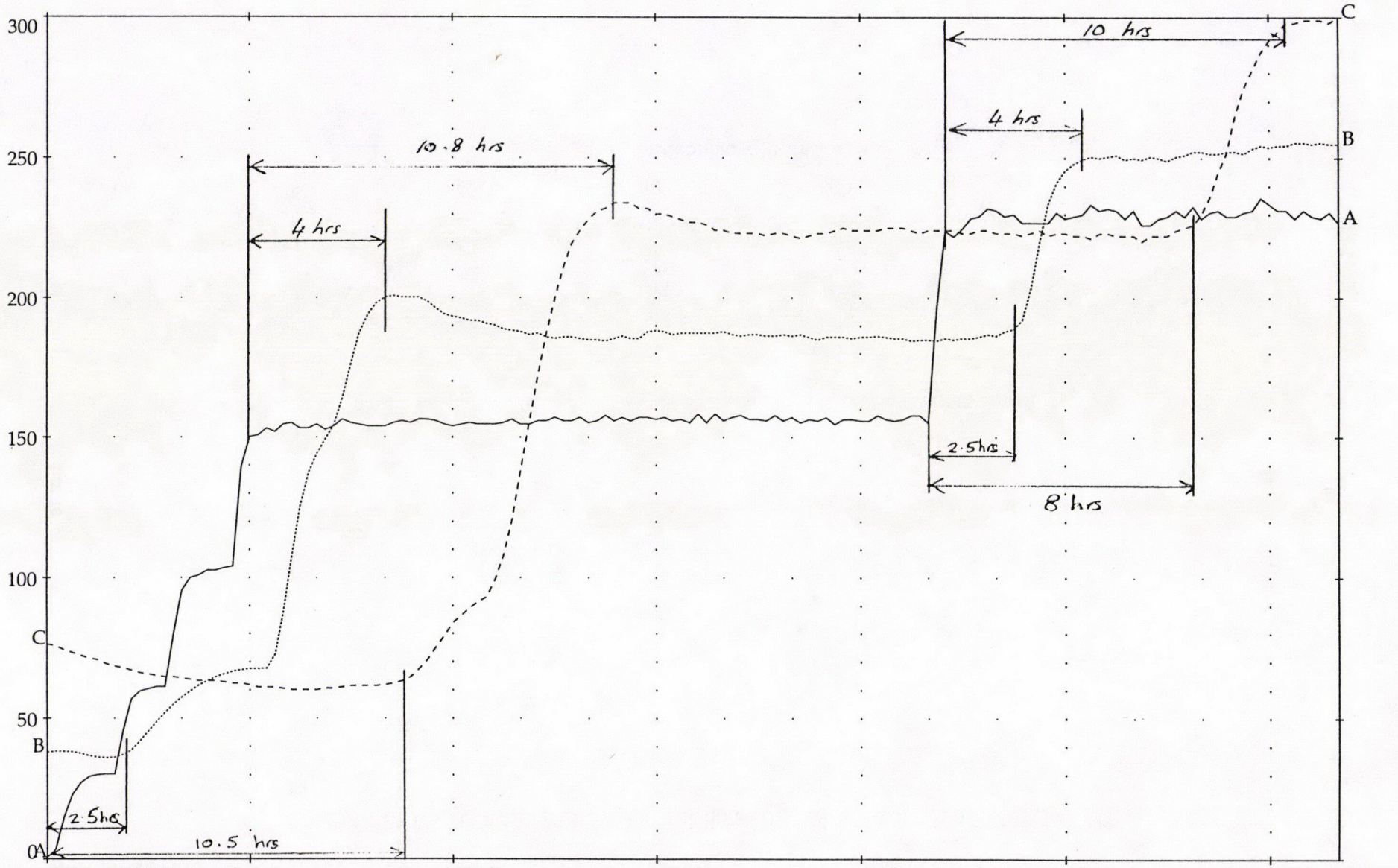

Time for Tuatapere flow to stabilise following increase in MLC outflow
hours
12
10
8
6
4
2
0
0
100
200
300
400
500
600
700
MLC outflow (cumecs)

FIGURE 5



A —— site 9552 Waiau River at Manapouri Lake Control ( )/1000 2units/mm
B ····· site 79735 Waiau River at Sunnyside ( )/1000 2units/mm
C - - - - site 79701 Waiau River at Tuatapere ( )/1000 2units/mm

FIGURE 6

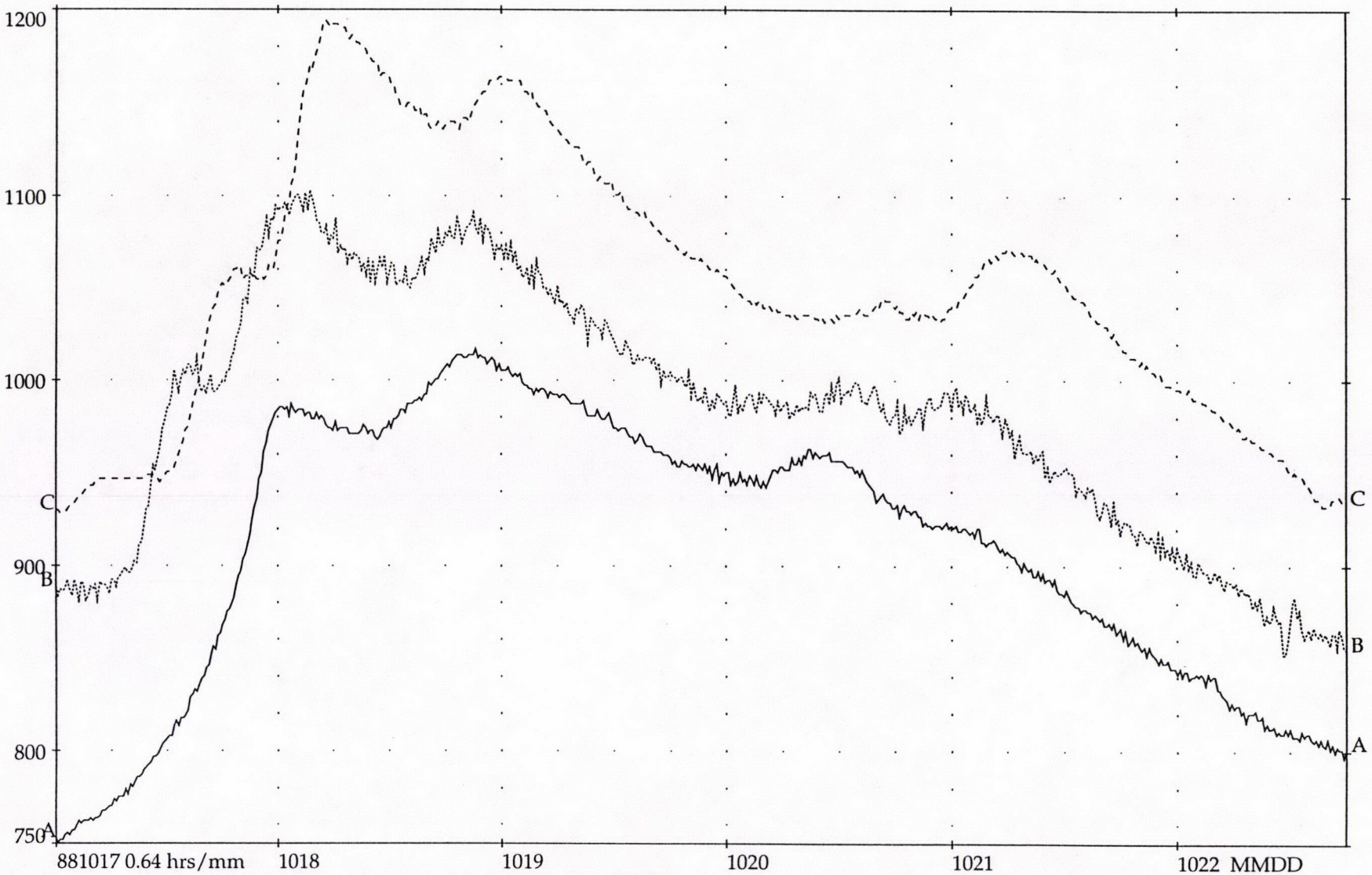

1200
1100
1000
900
800
750
C
B
A
C
B
A
881017 0.64 hrs/mm
1018
1019
1020
1021
1022 MMDD
A —— site 9552 Waiau River at Manapouri Lake Control ( )/1000 3.2units/mm Origin 750
B ..... site 79735 Waiau River at Sunnyside ( )/1000 3.2units/mm Origin 750
C - - - - site 79701 Waiau River at Tuatapere ( )/1000 3.2units/mm Origin 750

FIGURE 7

PART B FLOW RECESSION PROFILE

1. Objective

To see what happens to the flow profile as outflow from the Manapouri Lake Control (MLC) structure or Mararoa Weir is progressively reduced.

Knowledge of the flow recession profile and travel times will enable reasonably precise setting of downstream flows by appropriate manipulation of the lake control gates.

2. Method

In order to examine the flow profile from MLC downstream to Tuatapere it was necessary to select records where the influence of lower Waiau tributary inflows was minimal. In approximately 16 years of data only about a dozen flow recessions were identified as suitable for analysis.

3. Background

The MLC gates are operated according to a set of rules which are governed by either Manapouri Lake level or Mararoa River flow. These rules state that the gates must be opened in stages as the lake level and/or Mararoa River rises. Conversely the gates are closed in stages as the lake level and/or Mararoa River flow decreases.

Because the gate movements are "incremental" the outflow from the structure is stepped. A fairly typical gate closing sequence and associated downstream flow profiles is shown in Figure 1.

Note that while the stepping is less pronounced at Sunnyside and Tuatapere than at MLC, it is nevertheless still very evident.

4. Analysis

In each of the flow recessions examined the parameters recorded were MLC outflow before and after a gate adjustment; Sunnyside and Tuatapere flow before and after the gate adjustment; time for the impact of the gate adjustment to be noticed at Sunnyside and Tuatapere; and time for the flow to stabilise at Sunnyside and Tuatapere following a gate adjustment. These parameters are illustrated in Figure 2.

In this particular instance MLC outflows pre and post-adjustment were approximately 365 m^3/s and 290 m^3/s respectively. Outflow from MLC stabilised within 30 minutes of gate adjustment. Downstream adjustments were first noticed after 2 hours at Sunnyside and nearly 7 hours at Tuatapere. It took 4 hours for the flow to stabilise at Sunnyside and 11 hours for it to stabilise at Tuatapere.

5. Results

Flow recession times of travel are dependent upon the magnitude of MLC outflow. As the outflow decreases the travel time increases and this affects both the response times and flow stabilisation times. This difference is illustrated by comparing Figures 2 and 3. Figure 3 is the flow recession for an event where outflow was reduced from about 35 m^3/s to zero and in this case the travel times are nearly double those in Figure 2.

Taking data from several flood recessions Figures 4 and 5 show the variations in response and stabilisation times at Sunnyside and Tuatapere when compared with MLC outflow post gate adjustment.

The river distance from MLC to Sunnyside is approximately 30km. When MLC outflow is reduced to about 160 m^3/s or greater it takes only 2 hours for the flow reduction to begin at Sunnyside and about 4½ hours for the flow to stabilise.

Similarly for Tuatapere, which is about 81km down river from MLC, it takes about 6½ hours for the flow to begin dropping and 11 hours for the flow to stabilise.

As the MLC outflow is reduced below 160 m^3/s the response and stabilisation times increase correspondingly. When the MLC gates are closed completely it takes 5 hours for the flow reduction to be noticed at Sunnyside and at least 11 hours (and frequently longer) for the reduced flow to stabilise.

At Tuatapere the cessation of MLC flow is noticed after 13 - 14 hours and it takes upwards of 26 hours for the reduced flow to stabilise.

6. Flow Relationships

Figures 6 and 7 depict the relationship between MLC outflow and river flow at Sunnyside and Tuatapere. Flows plotted in these figures are those immediately before flow reduction commences as a result of MLC gate movements.

Figure 6 shows that a MLC outflow of 30 m^3/s roughly corresponds to a Sunnyside flow of 50 m^3/s and Figure 7 shows that it corresponds to a flow of 80 - 90 m^3/s at Tuatapere.

At the other end of the scale a MLC outflow of 400 m^3/s gives a flow of about 440 m^3/s at Sunnyside and 460 m^3/s at Tuatapere.

Therefore in general terms, with relatively normal tributary inflows, Sunnyside flow will be 30 - 40 m^3/s greater than MLC outflow and Tuatapere flow will be about 60 m^3/s greater than MLC outflow. Note that the long term median flows at the three sites are MLC - 0 m^3/s, Sunnyside - 31 m^3/s and Tuatapere - 62 m^3/s.

7. Summary

1. Flow reductions downstream of the MLC structure correspond in volume to the MLC reductions and are noticeably "stepped" in profile all down the river.

2. Flow reductions at MLC discharges greater than about 160 m^3/s are typically noticed at Sunnyside after 2 hours, and at Tuatapere 6½ hours after the gates are adjusted.

3. With reductions at higher discharges the river flow at Sunnyside steadies after 4½ hours and the river flow at Tuatapere steadies after about 11 hours.

4. When the gates are closed completely (outflow shut down to zero) the flow at Sunnyside begins to decrease after 5 hours and at Tuatapere not until after 13 - 14 hours.

5. When the gates are closed completely the decreased flow at Sunnyside stabilises after 11 hours and at Tuatapere after about 26 hours.

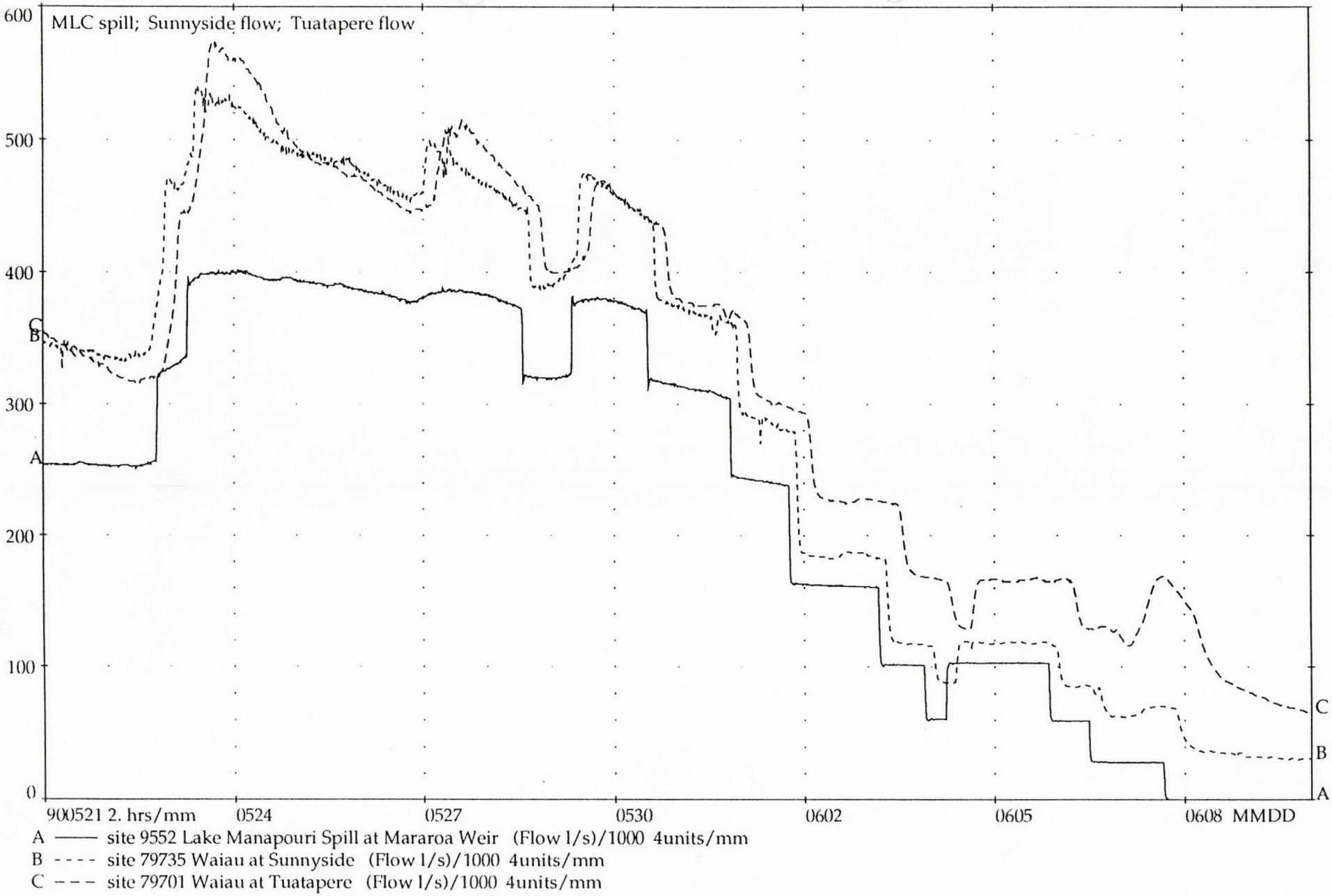

MLC spill; Sunnyside flow; Tuatapere flow
600
500
400
300
200
100
0
C
B
A
900521 2. hrs/mm
0524
0527
0530
0602
0605
0608 MMDD
A —— site 9552 Lake Manapouri Spill at Mararoa Weir (Flow l/s)/1000 4units/mm
B - - - - site 79735 Waiau at Sunnyside (Flow l/s)/1000 4units/mm
C – – – site 79701 Waiau at Tuatapere (Flow l/s)/1000 4units/mm

FIGURE 1

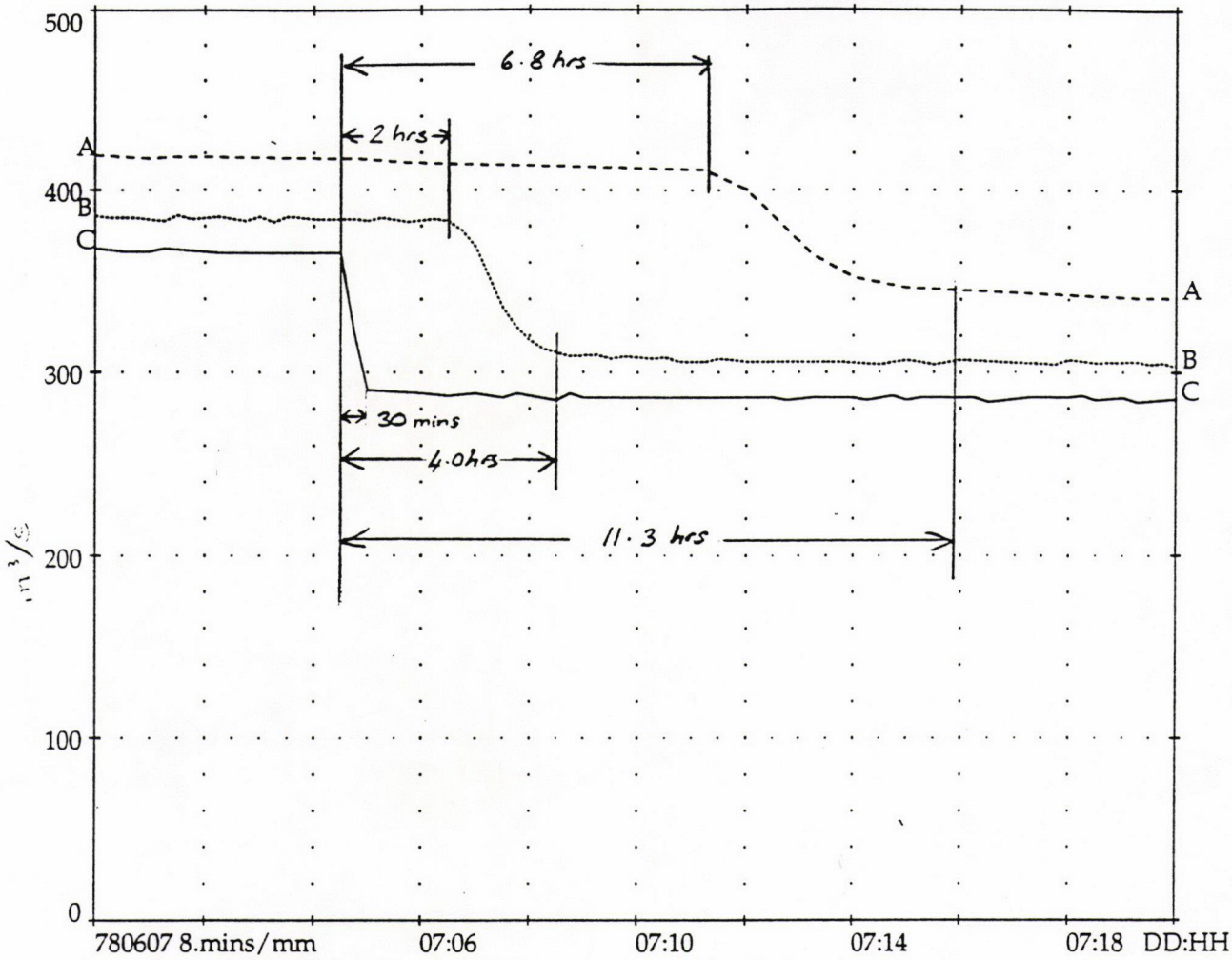


FIGURE 2

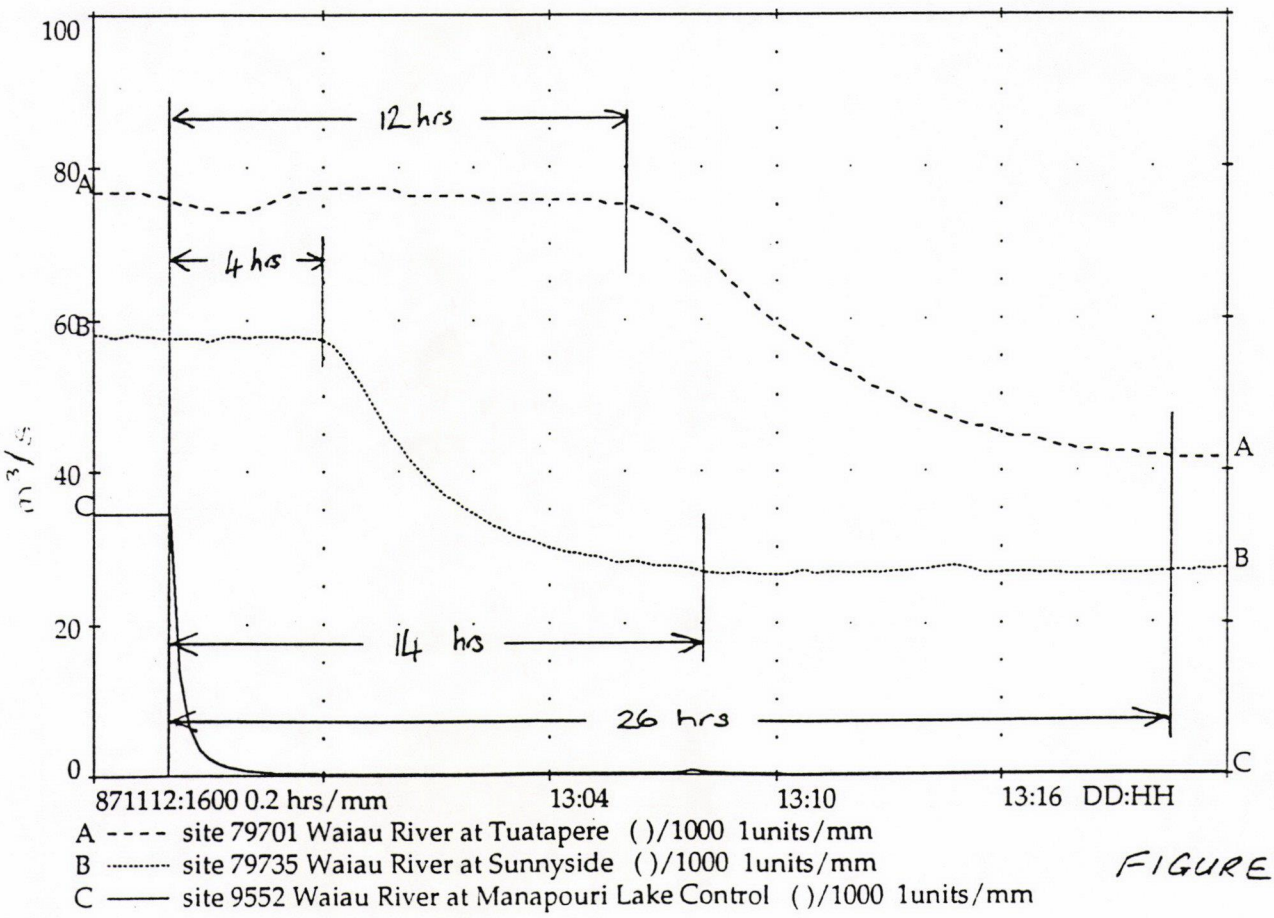


FIGURE 3

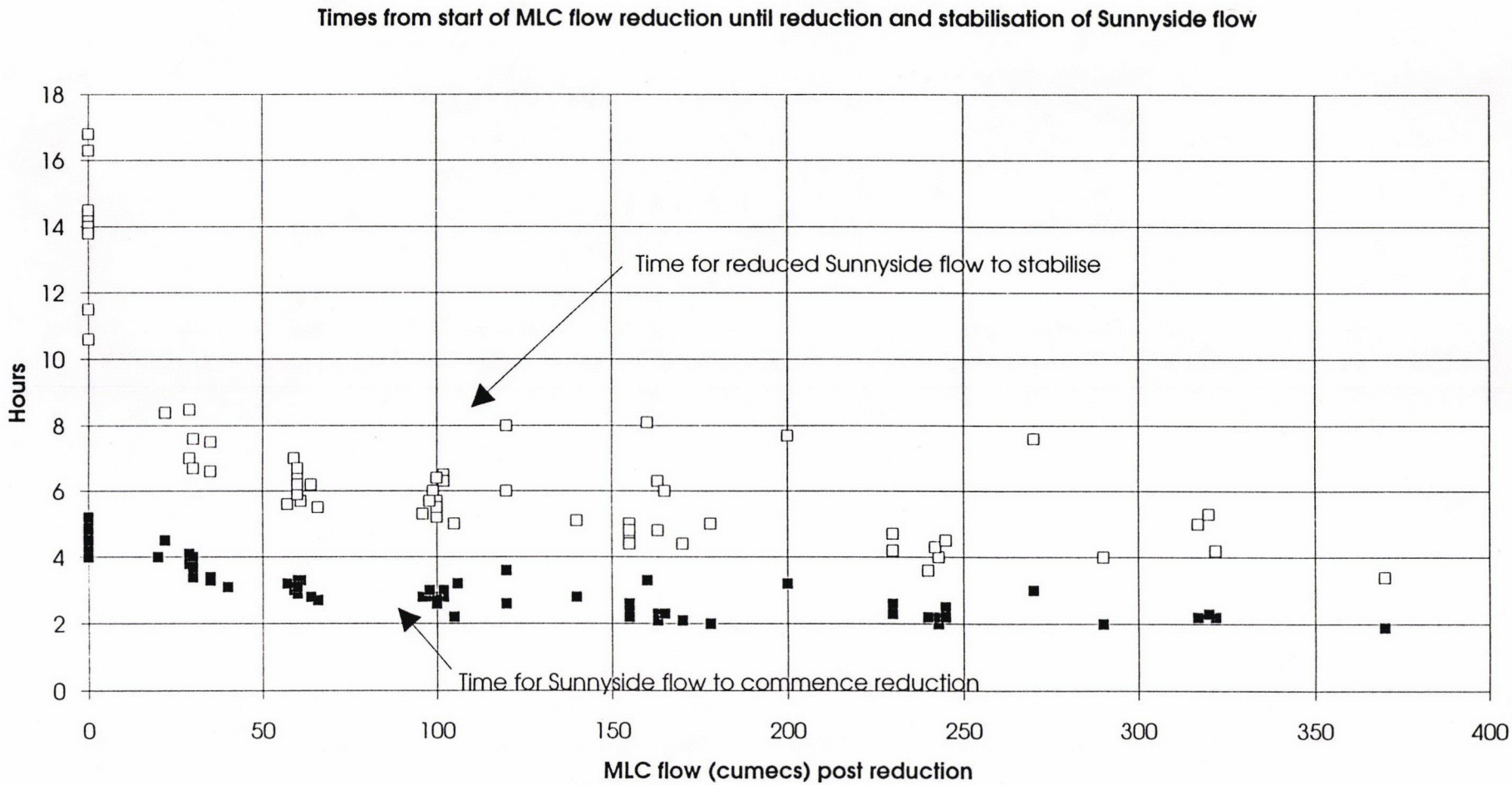

Times from start of MLC flow reduction until reduction and stabilisation of Sunnyside flow
Hours
18
16
14
12
10
8
6
4
2
0
Time for reduced Sunnyside flow to stabilise
Time for Sunnyside flow to commence reduction
0
50
100
150
200
250
300
350
400
MLC flow (cumecs) post reduction

FIGURE 4

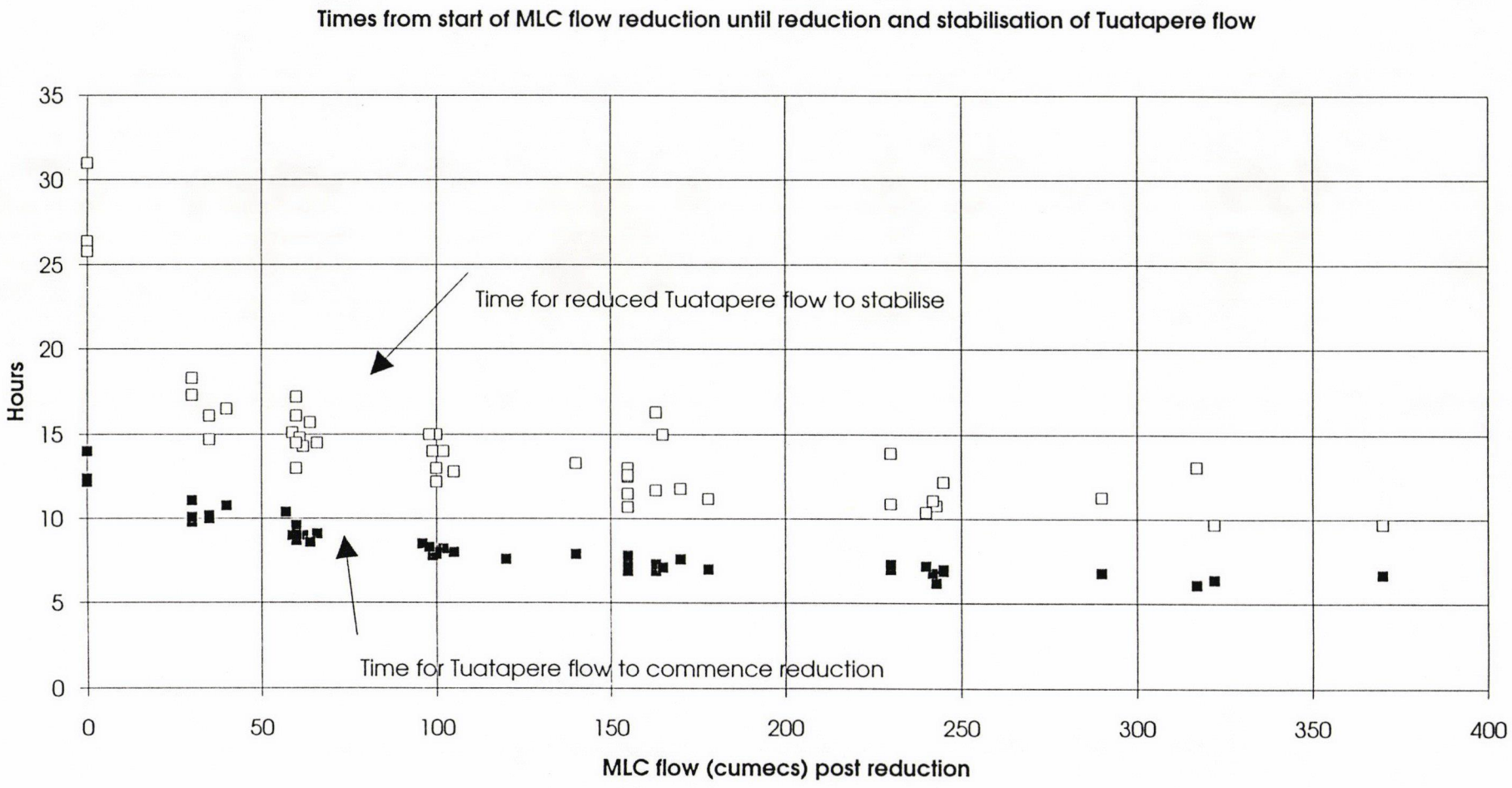

Times from start of MLC flow reduction until reduction and stabilisation of Tuatapere flow
Hours
35
30
25
20
15
10
5
0
0
50
100
150
200
250
300
350
400
MLC flow (cumecs) post reduction
Time for reduced Tuatapere flow to stabilise
Time for Tuatapere flow to commence reduction

FIGURE 5

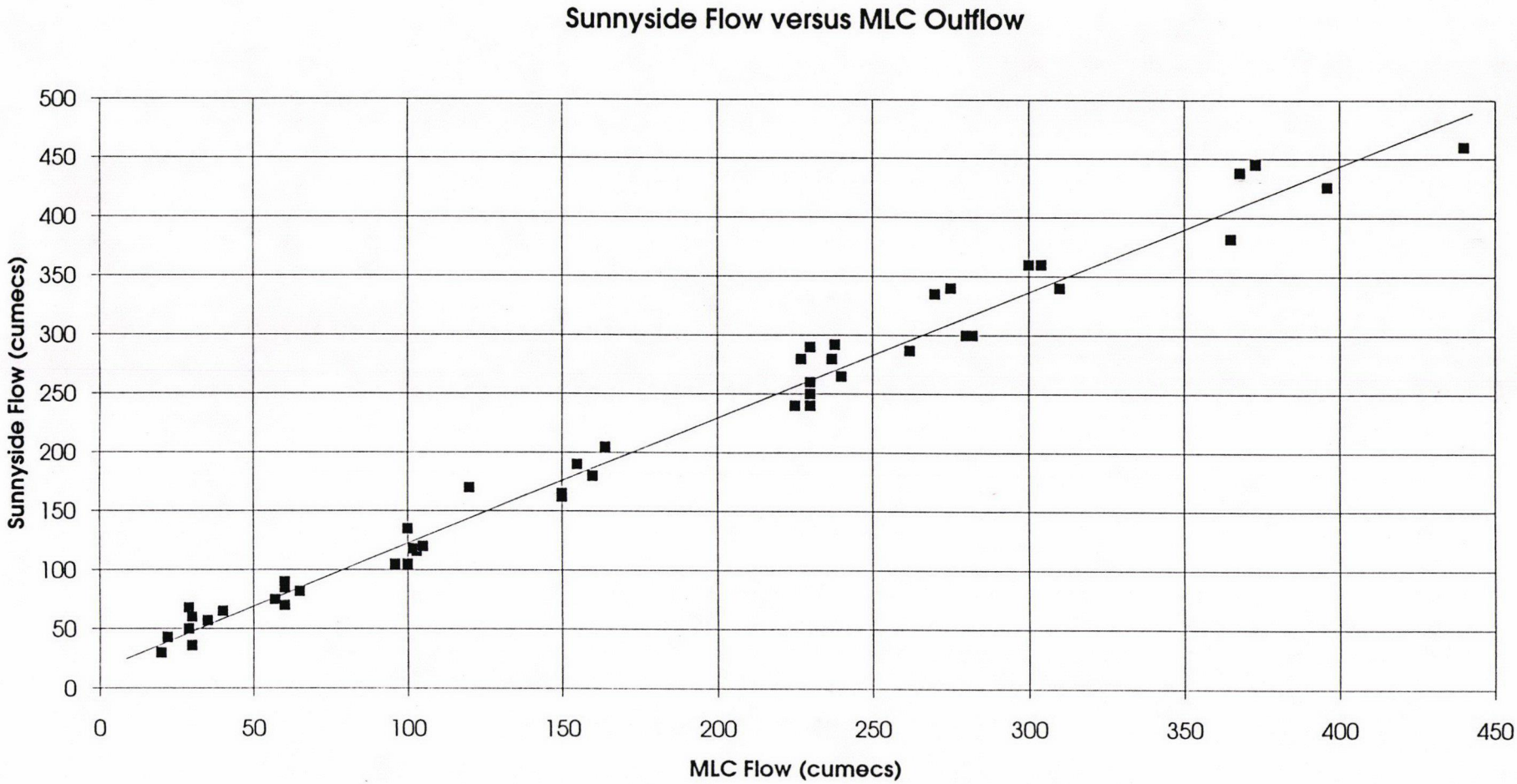

Sunnyside Flow versus MLC Outflow
Sunnyside Flow (cumecs)
MLC Flow (cumecs)
0
50
100
150
200
250
300
350
400
450
500

FIGURE 6

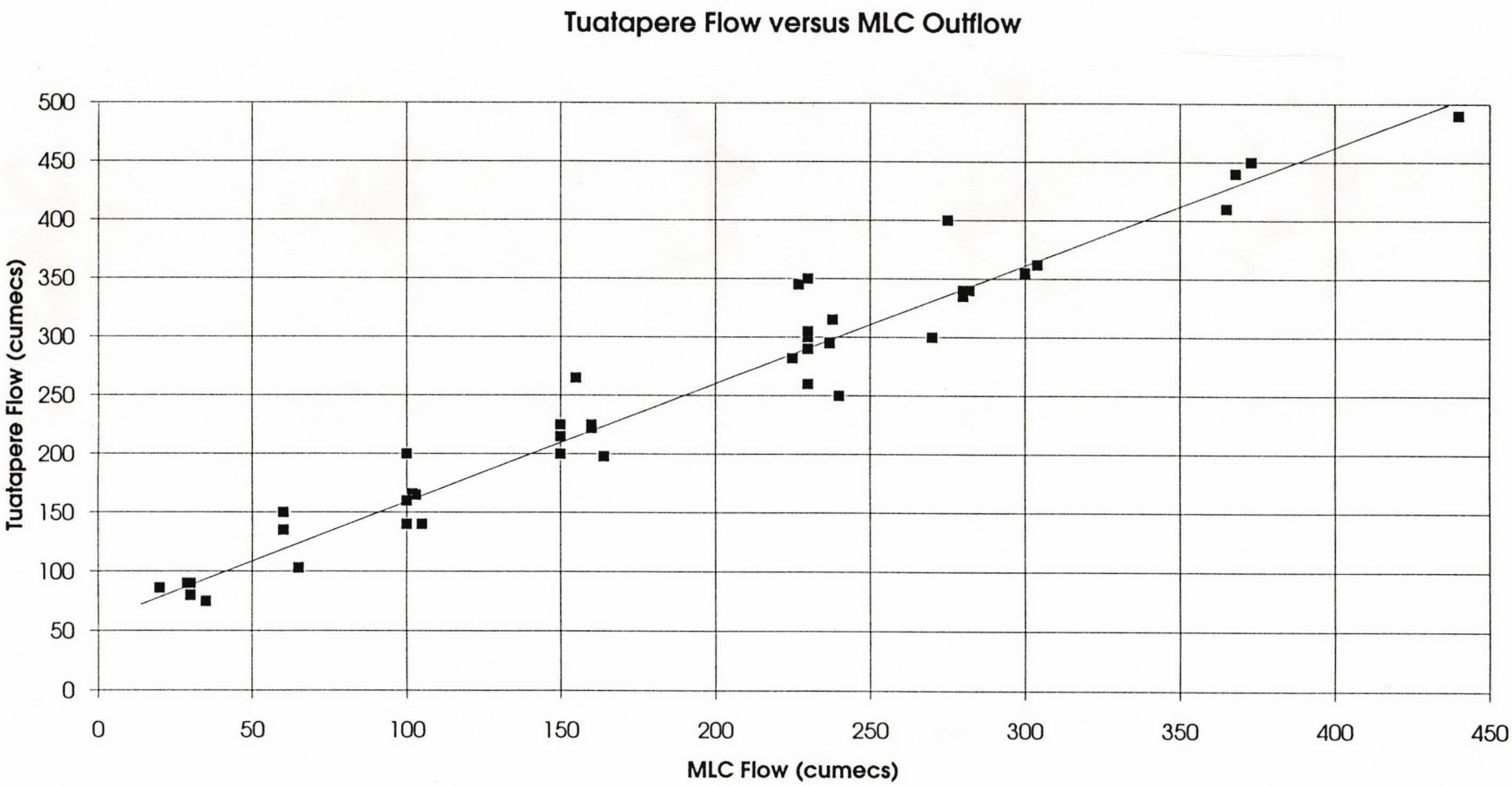

Tuatapere Flow versus MLC Outflow
Tuatapere Flow (cumecs)
MLC Flow (cumecs)
0
50
100
150
200
250
300
350
400
450
500

FIGURE 7

Application of Results

Assume the MLC gates are initially closed and that a jet boat run up-river from Clifden to Monowai is planned for Saturday commencing at 10:00am and finishing back at Clifden at 4:00pm. Assume that 35 cumecs is required to be spilled from the control gates.

11 hours is required for MLC outflow to stabilise at Tuatapere. Clifden is some 15km upstream of Tuatapere and so the time required for flow to stabilise here is about 9 hours. This implies the control gates should be opened at 1:00am on Saturday morning to allow sufficient time for the water to reach Clifden by 10:00am.

When the MLC gates are closed it takes 4 hours for the flow reduction to show at Sunnyside and 12 hours for the flow reduction to show at Tuatapere (this will equate to about 10 hours at Clifden).

If the jet boats are to leave Monowai at say 1.00pm (to go back downstream) then the MLC gates could be closed 4 to 5 hours before then - say at 9:00am on the Saturday morning.

If the jet boat run were to go upstream as far as the control gates then the gates could be closed any time after the boats had left this stretch of the river.