Recalibration of Tuggerah Lakes Model and Evaluation of The Entrance dredging impacts February 1999

Lawson & treloar pty ltd

Flooding dredging

34

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16 February, 1999

Wyong Shire Council
PO Box 20
WYONG NSW 2259

Our Ref: J1710/L7340
Attn: Tom Wallace

Dear Tom,

RE: RECALIBRATION OF TUGGERAH MODEL AND EVALUATION OF ENTRANCE DREDGING IMPACTS

To assess the impacts of widening and deepening the entrance channel to Tuggerah Lakes, the existing MIKE–11 model, originating from the Flood Plain Management Study, was updated with survey information for Wyong River and Ourimbah Creek acquired for the Flood Forecast study. To further improve the model it was also updated to a newer version of MIKE–11.

In comparison to the original model from the Floodplain Management Study, the new model is updated to MIKE–11 version 3.2, which will have some minor effects on the results, but will also improve the stability of the calculations. To improve the creek and river description, the new model was also updated to include detailed survey information for cross sections and bridges on the Wyong River and Ourimbah Creek and the description of Wallarah Creek was extended further upstream to utilise the available data. The only difference between the new model and the Flood Forecast model is therefore that, because for technical reasons the MIKE–11FF module could not handle multiple structures, the weirs and culverts were combined into one structure, whereas they have been properly represented as separate structures in the new tidal model. In the future, when a new updated version of the MIKE–11 Flood Forecast module becomes available, this new tidal model should replace the existing forecast model.

Because the purpose of this study was to analyse the tidal influence in the Tuggerah Lakes, it was necessary to modify the river/creek branches of the model to avoid

instabilities generated in dry parts of the system. For most of the system, the bed level is below 0.0 m AHD, but for Wallarah Creek and Ourimbah Creek it was necessary to add either dummy weirs to hold back a trickle of water, or to adjust the extent of the modelled part of the creek.

TIDAL CALIBRATION

In the Floodplain Management Study it was shown that the lake levels are affected predominantly by the entrance conditions. Because the entrance conditions vary significantly due to littoral processes, it was crucial that the calibration was carried out for a corresponding set of entrance survey and lake level gaugings.

For the tidal calibration, the model was updated with the entrance conditions as surveyed at the end of March 1996 and the model was calibrated to a set of corresponding water level gaugings for the period of 20/03/96 to 06/04/96. The calibration was carried out for three water level gauges, namely Toukley and Long Jetty, located at either end of Tuggerah Lake, and the gauge in the entrance channel located approximately 40m west of the bridge, Figure A. The survey data for the entrance channel are shown in Figure B. The location of these sections is shown on Figure C.

The calibration was carried out using an observed tide from Sydney Harbour for all of 1996. The whole series was applied subsequently to the calibrated model to calculate mean values for lake level and tidal range for the lakes. Where data were missing the tide has been updated with data predicted using standard parameters for Sydney Harbour. The recorded tide is shown in Figure 1.

Comparing gauged water levels for Toukley and Long Jetty shows little difference over the lake, whereas gauged levels from the entrance station, 50m west of the entrance bridge at The Entrance, show a significant reduction from the ocean tidal range, indicating a significant hydraulic loss between the bridge and the ocean. The hydraulic loss between the bridge and the ocean is made up of a combination of friction loss, head loss around the bridge and expansion loss where the entrance meets the ocean.

The friction loss was simulated by calibrating the roughness parameter for the river, lake and entrance branches. Because the friction loss over the lakes will be negligible, it was difficult to calibrate the lake friction parameter and it was set to an appropriate value based on experience. Likewise the upper river and creek branches will have little effect on the lake levels for a tidal calibration, and these roughness parameters were set at values found in the Flood Plain Management Study.

To simulate the entrance loss, the entrance channel was split in two successive parts with the first part describing the actual entrance channel and the second part describing the ocean mouth. To account for the higher hydraulic loss between the bridge and the ocean, the channel describing this part was given a higher friction loss parameter than the part closer to the lake. Likewise, the ocean mouth channel was

given a high roughness parameter to account for the expansion loss at the ocean mouth.

There was no available survey information for the bridge over the entrance channel, but because initial calibration results indicated that it would have an impact on the total hydraulic loss, it was included by approximating the bridge layout using data from the nearest cross section. Through calibration it was found that by approximating the weir/culvert structures from data for this cross section, which was located virtually at the site of the bridge, it was possible to obtain a very good fit to the gauged data. For future investigations it is recommended that council obtains survey data for the bridge.

The calibration results are shown in Figure 2 and generally the results show a very good fit to all three gauges both with respect to timing, absolute water level and tidal range. Initially there is a slight deviation for both lake gauges, but because the fit is quite good for the entrance gauge this is believed to be caused by local conditions, such as wind setup, that were not included in the calibration. However, excluding this deviation the overall accuracy of the calibration is approximately +/– 0.05m, which is quite good.

LAKE BEHAVIOUR

To describe the normal lake behaviour, the model was run for all of 1996 and the predicted lake levels were compared to the actual gaugings at Toukley and Long Jetty. The results of this comparison are shown on Figures 3 and 4.

Generally the fit between modelled and gauged lake levels is good, but there are some deviations with respect to timing, peak values and volume. This however, is to be expected because the model was run as a tidal model without taking either wind or rainfall conditions into account. It is therefore most likely that explanations for deviations in peak levels and volumes could be found by examining rainfall records. Likewise, minor deviations in peak levels might be explained using wind data, whereas deviations in timing might be caused by a combination of meteorological conditions and changing morphological conditions for the entrance channel. However, a further investigation into these deviations is outside the scope of this project. Finally, it should also be noted that there are obvious physically unrealistic spikes in the recorded data, probably due to errors in the gauging instruments.

Accepting the model as giving a quite good reproduction of the lakes tidal behaviour, the average lake level and tidal range were calculated by extracting and analysing data for a specific location in Tuggerah Lake near the confluence with the entrance channel. Using this approach the mean conditions for 1996 were found to be:

Mean lake level	=	0.16m AHD
Lake level range	=	0.00 – 0.30m

It should be noted though, see Figures 3 and 4, that the lake is significantly influenced by the mean ocean level as indicated by the two episodes of low lake levels in March

and October. As these " lows" appear in both the modelled and the gauged data, and because the model is only influenced by the ocean tide, these fluctuations must be generated by minor changes in the mean ocean level. Scrutinising the recorded tide data, Figure 1, does show slightly lower ocean levels in these periods, but the fluctuations are relatively far less pronounced in the ocean than their impacts on the mean lake level. The fact that this pattern is reproduced by the model further strengthens the confidence in the calibration, although it should be stated that the first " low" actually coincides with the calibration period.

IMPACTS OF WIDENING AND DEEPENING THE CHANNEL

To evaluate the impacts of widening and deepening the entrance to provide access for proposed fast ferries, the calibrated model was adjusted for proposed entrance changes and the 1996 tides re-simulated. Based on requirements specified by the ferry operators, three scenarios were found to be of interest for the evaluation:

A. Widening to min. 45 m and deepening to -1.6m ISLW
B. Widening to min. 45 m and deepening to -3.0m ISLW
C. Widening to min. 45 m and deepening to -4.0m ISLW

It should be noted that ISLW (Indian Spring Low Water) is about 0.93m below AHD in the ocean and that unlike AHD, ISLW varies spatially.

When modelling the impacts of deepening and widening the entrance channel for ferry operation, it has been assumed that the channel will be dredged from the ocean and back to the bridge. In reality this is hardly feasible, as the jump in bed level between the bridge and the dredged channel is likely to collapse, but addressing this problem and further channel dredging beyond the bridge is outside the scope of this study.

The impacts of widening and deepening the entrance channel have been addressed by comparing the resulting mean lake level, annual high and low lake levels and average tidal range to those of the existing situation. The existing situation, however, has been defined as that being described by the surveyed data from late March 1996, which is slightly unfortunate because the channel was dredged just prior to the survey being carried out. The implications of this dredging are that the channel will have little impact on the existing situation as tested for 1996, which of course would be different if the channel had been less open. However, as it is a known fact that the entrance channel is significantly affected by littoral processes, it will always be difficult to define reasonable " existing" conditions. Therefore a range of "existing" conditions should be examined to describe the sensitivity of the results to pre-dredging entrance conditions.

As anticipated in the previous paragraph, the three options, A, B and C, will have little impact on the existing conditions. As expected, the wider, deeper entrances allow a greater tidal range in the lake, see Table 1. The lack of major impact is primarily related to the proposed widening being minor compared to the existing width of the channel, but there will be some effects from lowering the bed level.

In Figure 5 the probabilities of exceedance of lake-level have been presented for the existing situation and the three proposed dredging options. A comparison of the high and low water levels shows that there is little difference at these extremes. Table 1 shows also that the mean lake level reduces progressively. This result is expected, because although a wider and deeper channel will allow more of the tidal range to be transferred to the lake itself, the greater depth and width of the dredged channel will have little impact on the maximum levels, although a deeper channel will allow lower tides.

Table 1 Impacts of dredging the entrance channel

	Lake Level (m AHD)			
	Mean	**Minimum**	**Maximum**	**Mean Tidal Range (m)**
Existing (Calib96)	0.17	0.00	0.30	0.026
Option A	0.15	-0.04	0.30	0.031
Option B	0.13	-0.07	0.31	0.033
Option C	0.12	-0.09	0.32	0.042

These results demonstrate that the system is very non-linear. They confirm the deduction made above and in general it can be concluded that the proposed dredging options will have little impact on the existing conditions, assuming that the entrance is maintained by regular dredging. If necessary, impacts on more restricted "existing" entrance conditions can be addressed in another study if suitable survey information can be made available.

QUALIFICATIONS

This report has been prepared by Lawson and Treloar (L&T) specifically for Wyong Shire Council and specifically to provide advice on impacts of the proposed widening and deepening of the entrance channel to Tuggerah Lakes.

Our analysis and overall approach have been specifically undertaken for the particular requirements of Wyong Shire Council and may not be applicable beyond this scope. For this reason any other third parties are not authorised to utilise this report without further input and advice from Lawson and Treloar.

The report is based on the following studies and information prepared by others:

1. L&T has relied on water level gaugings provided by:

   -Wyong Shire Council

   The accuracy of these gaugings limits the accuracy of the tidal calibration.

2. L&T has relied on survey data provided for earlier studies by:

   -Wyong Shire Council

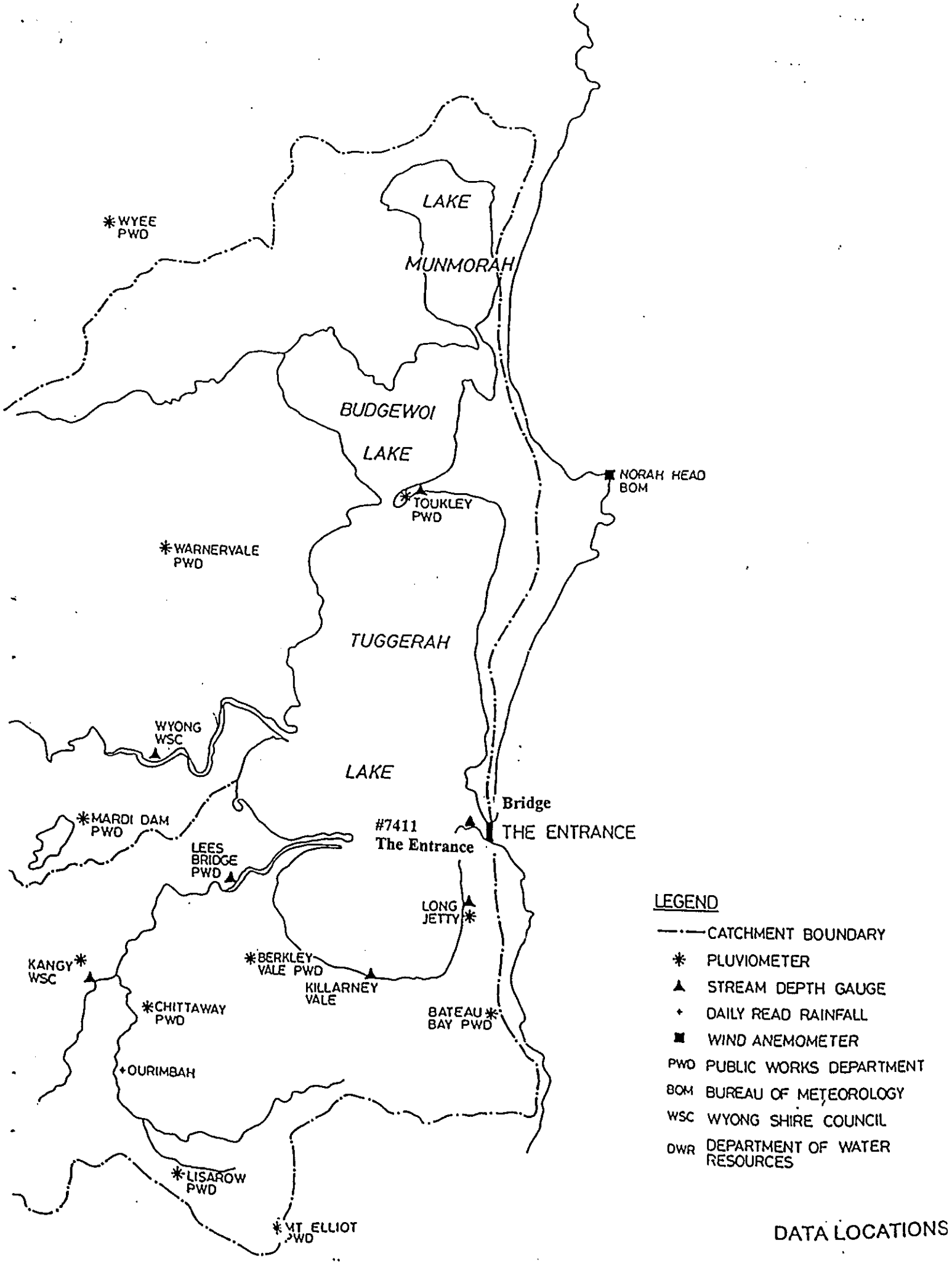
   The accuracy of these survey data limits the accuracy of predictions.

While L&T's model accurately assesses the impacts on a tidally influenced system, this model has not been calibrated for either floods or flood forecasting and is therefore not suitable for any of those purposes, unless additional flood re-calibration is undertaken.

We hope that this work has been undertaken to your satisfaction. Should you have any questions we would be pleased to address them.

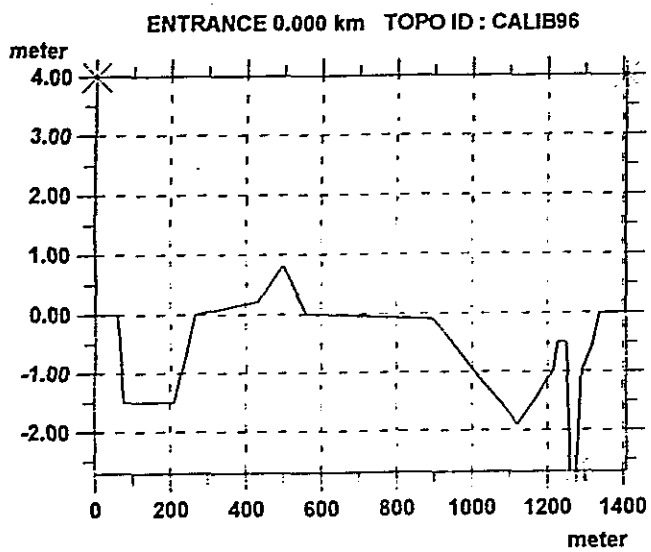
Yours faithfully
Lawson and Treloar Pty Ltd

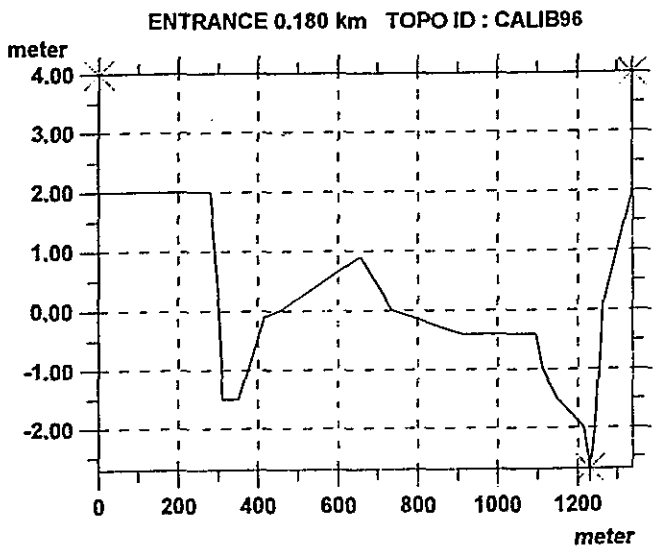
Katja M. Goodhew

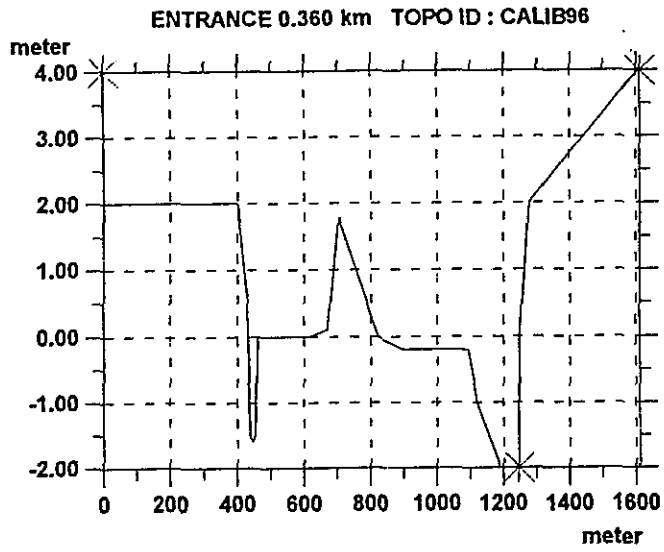


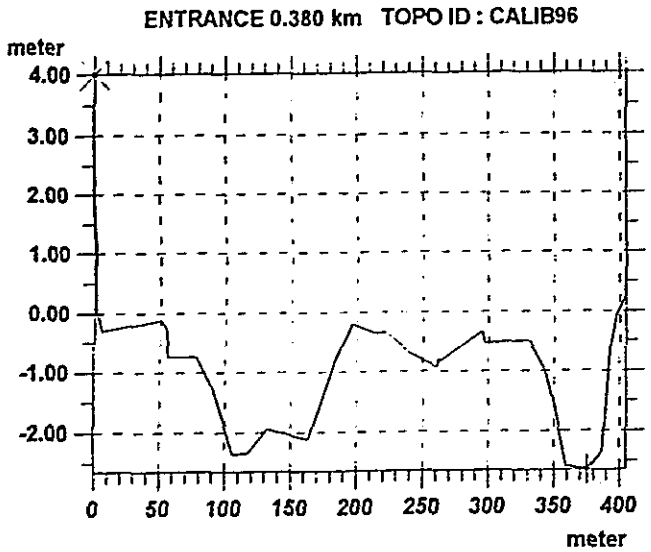
DATA LOCATIONS

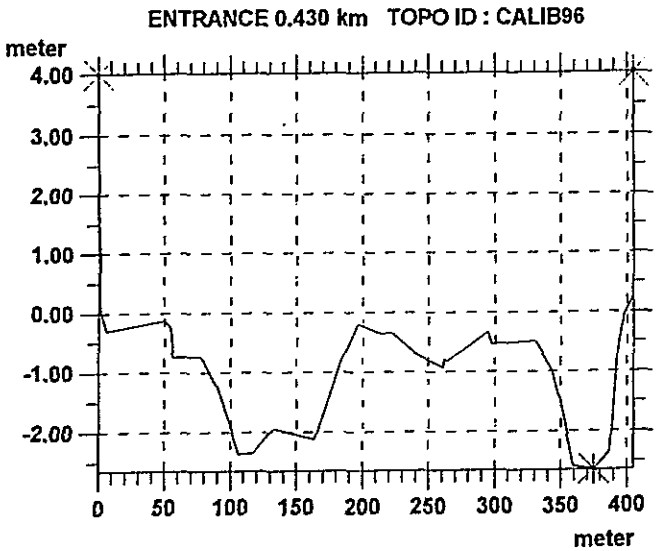
Figure A

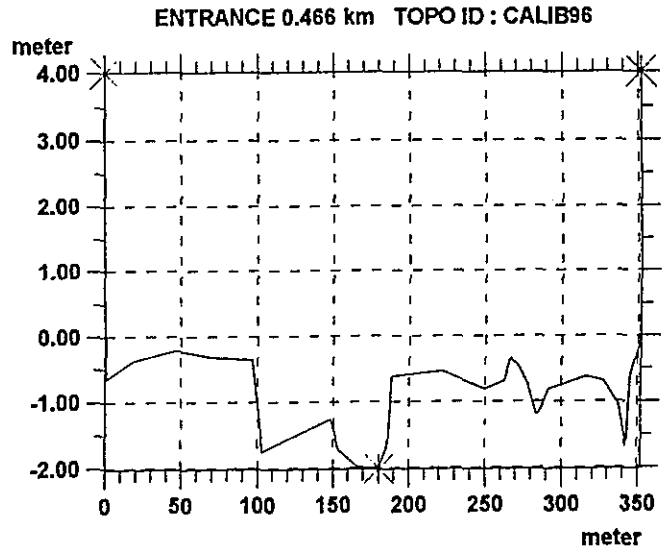




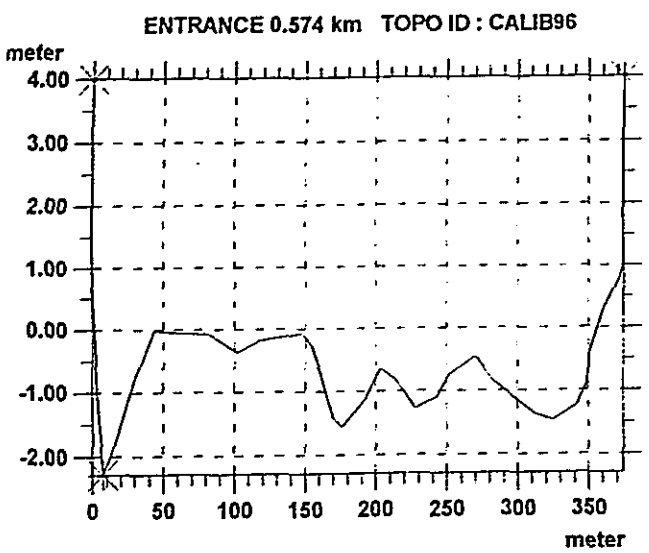


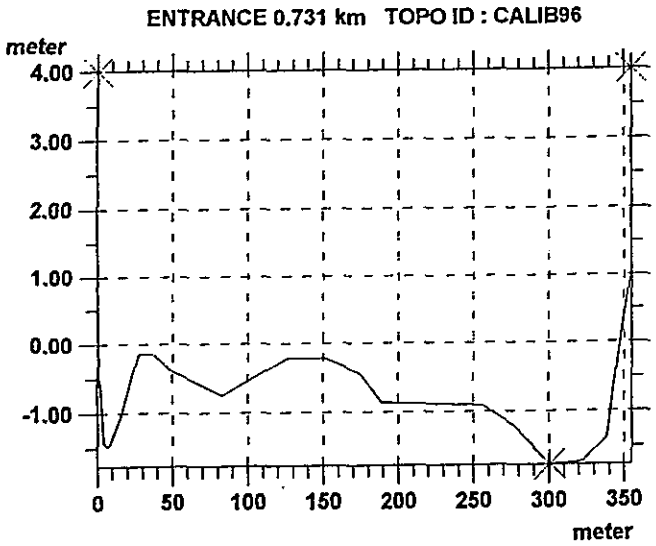


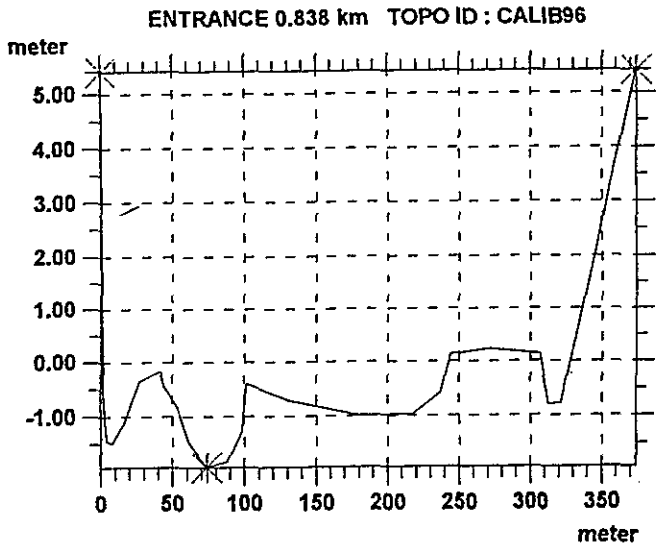


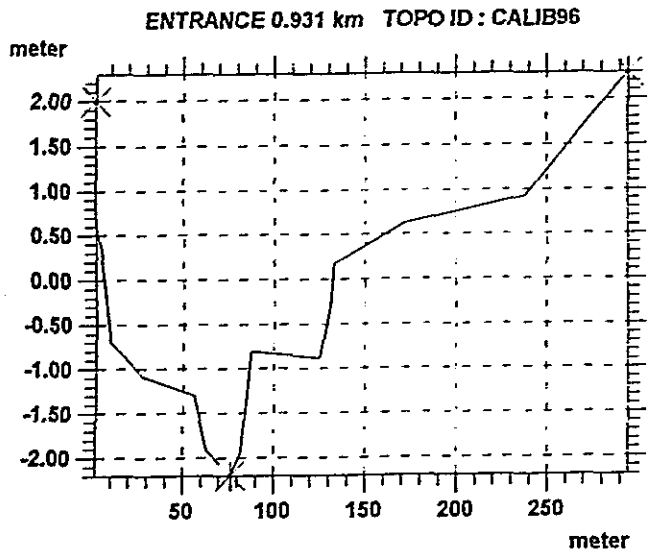


	J1710 Tuggerah Lakes - Recalibration of model March 1996 Survey Data for Entrance Channel Figure B
DATA BASE : J1710	MIKE 11









	J1710 Tuggerah Lakes - Recalibration of model *March 1996 Survey Data for Entrance Channel* Figure B
DATA BASE : J1710	MIKE 11

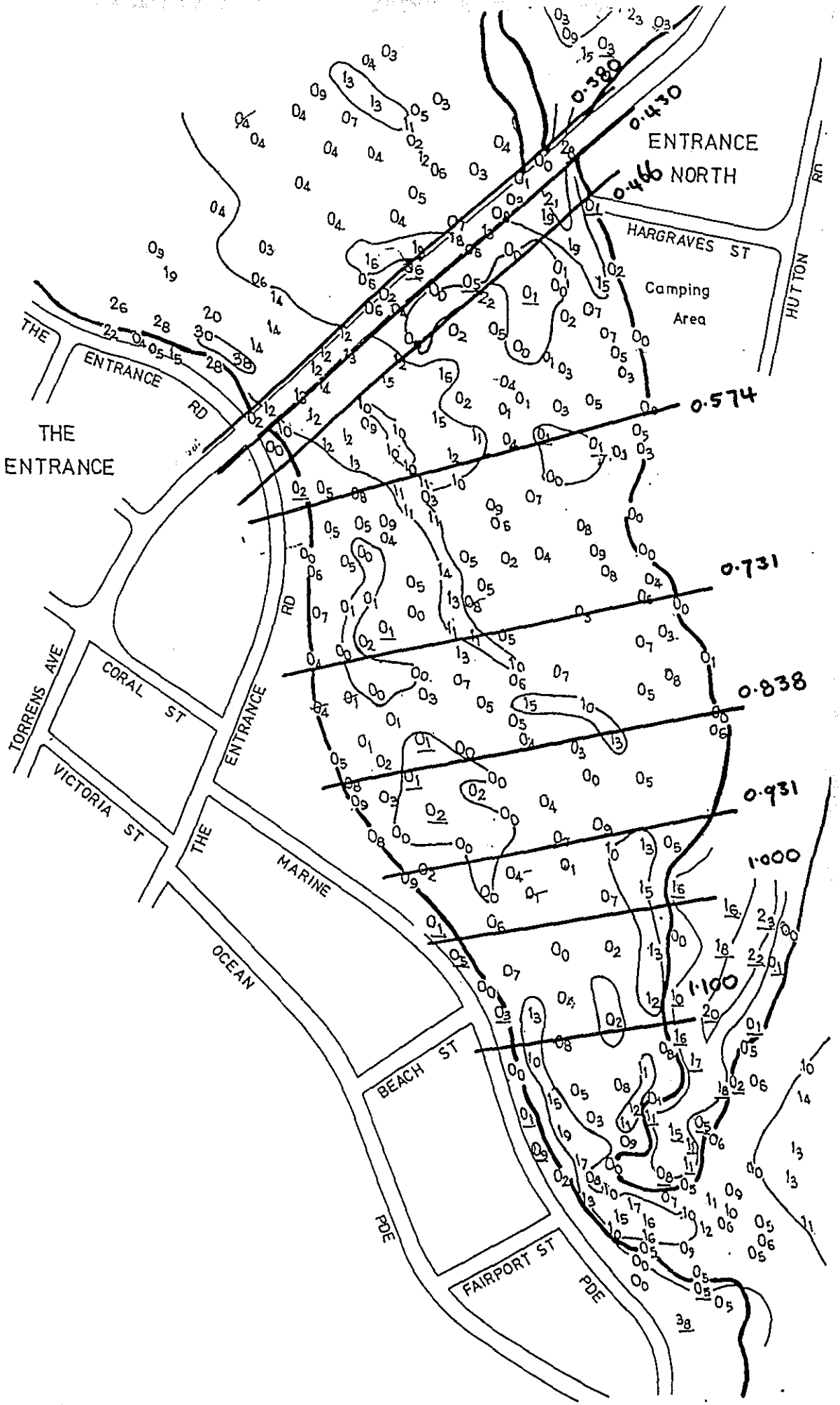

0.380
0.430
0.466
0.574
0.731
0.838
0.931
1.000
1.100
ENTRANCE NORTH
HARGRAVES ST
HUTTON RD
Camping Area
THE ENTRANCE
THE ENTRANCE RD
TORRENS AVE
CORAL ST
VICTORIA ST
ENTRANCE RD
THE MARINE
OCEAN
BEACH ST
PDE
FAIRPORT ST
PDE

DIAGRAM 'C'

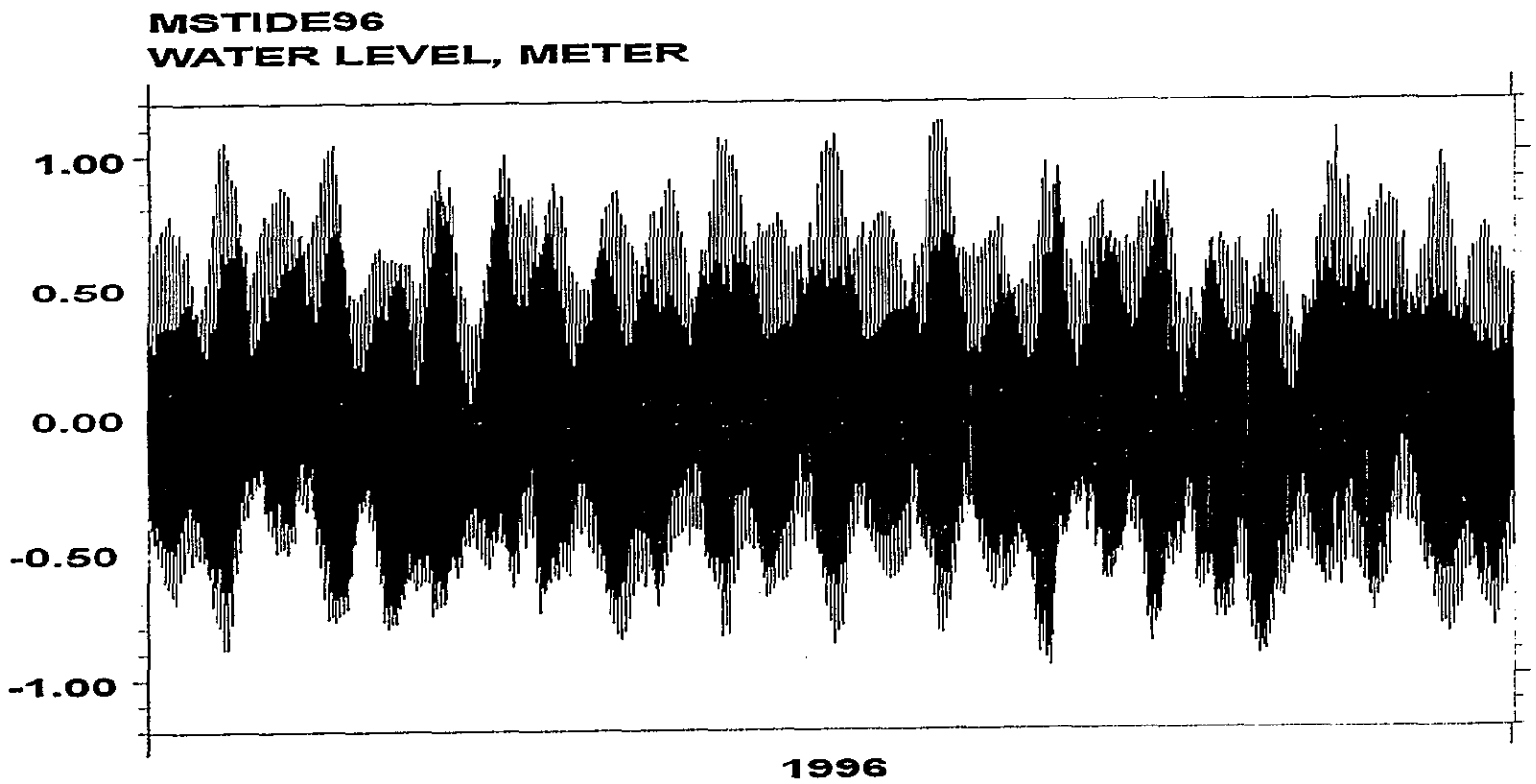


Figure 1
Recorded Tide

MIKE 11

TIME SERIES DATA BASE MSTIDE96

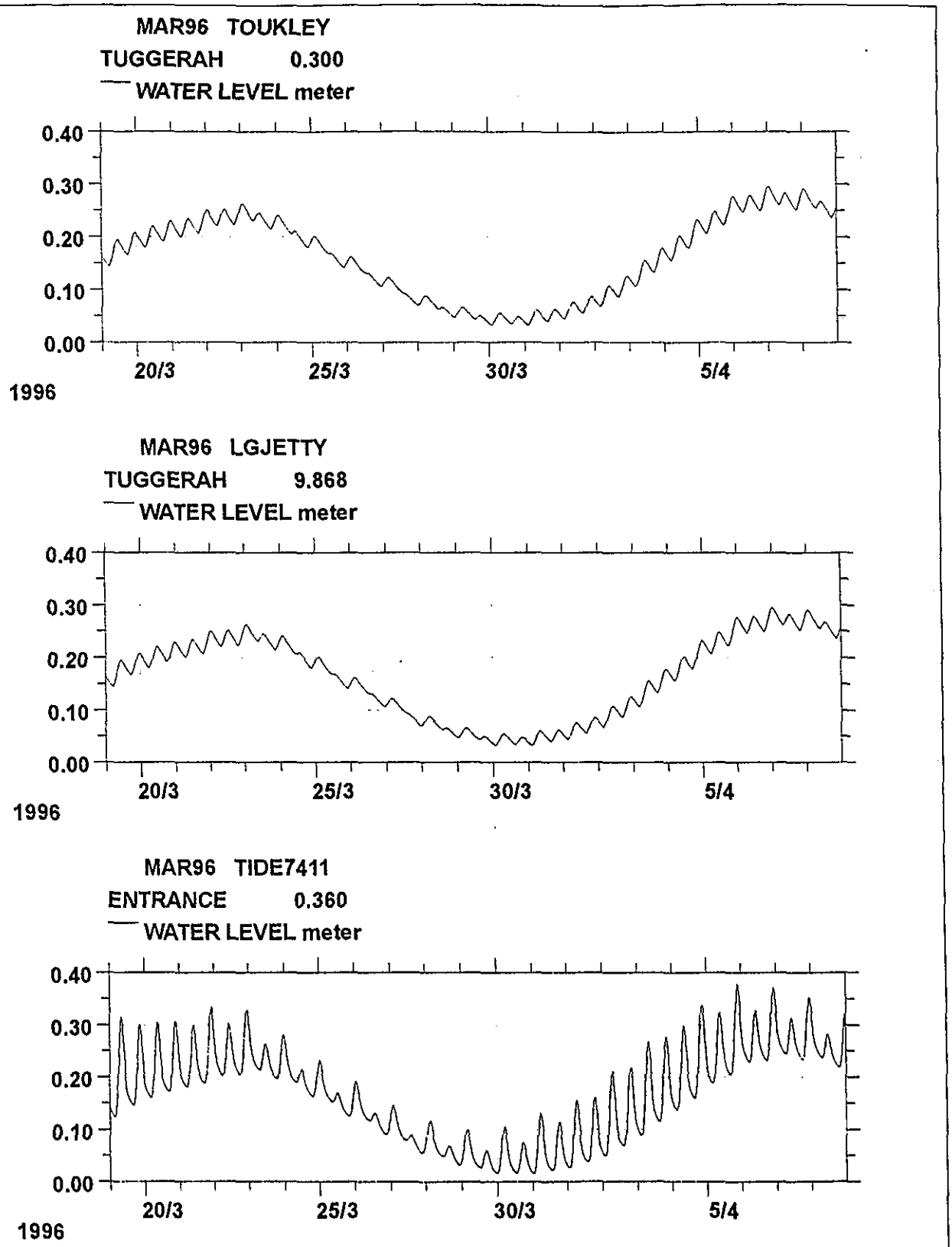


Figure 2 Calibration Results	J1710 Recalibration of Tuggerah Model Calibration runs for March 1996 14.01.99/KMG
DATA FILE : CALIB96.RDF RESULT FILE CALIB96.RRF	BOUNDARY FILE: STIDE96.BSF CALCULATED: 13-JAN-1999, 18:24

MIKE 11

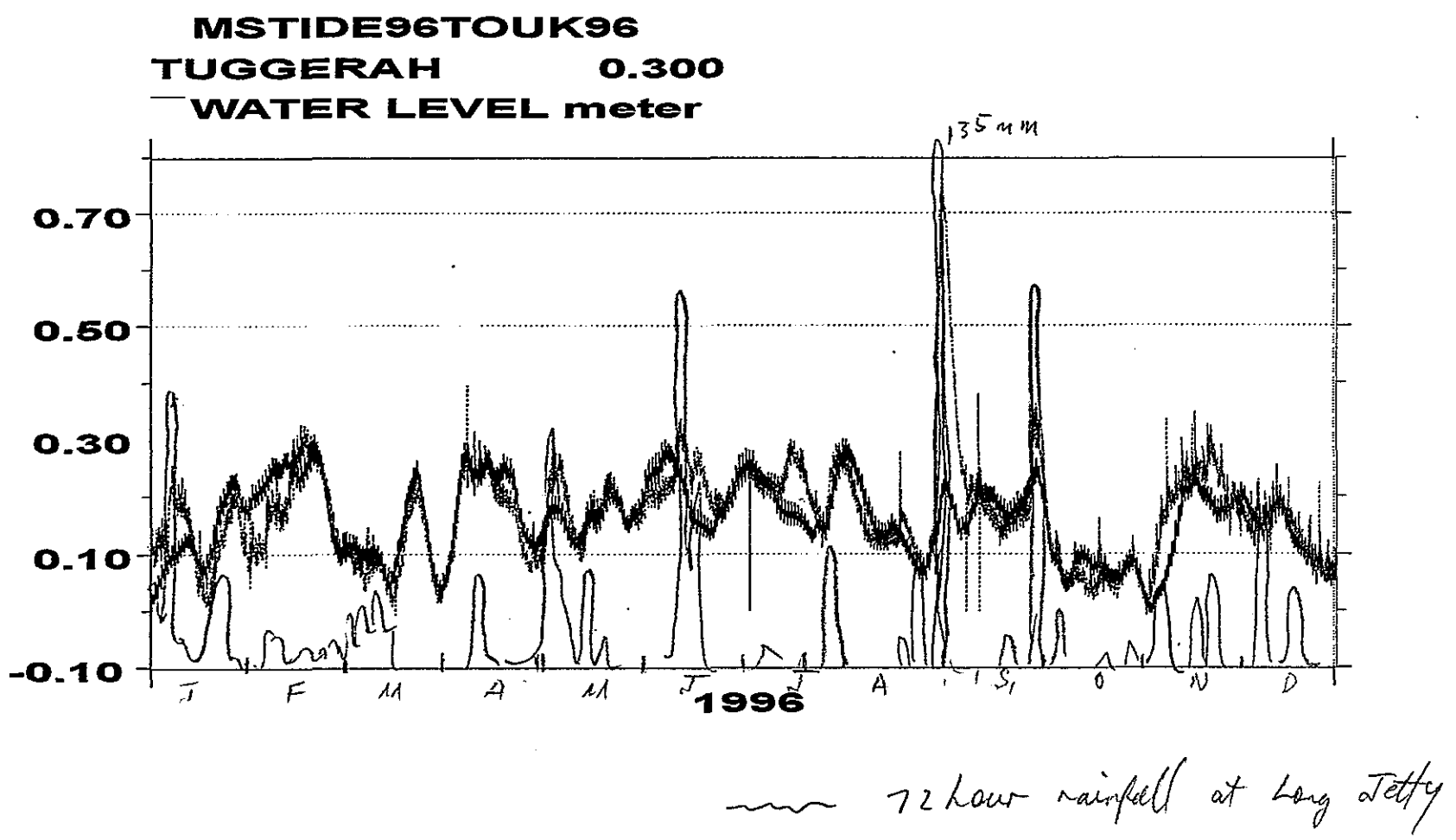


Figure 3
Toukley

J1710 Recalibration of Tuggerah Model
Calibration runs for March 1996
14.01.99/KMG

DATA FILE : CALIB96.RDF **BOUNDARY FILE: MSTIDE96.BSF**
RESULT FILECALIB96.RRF **CALCULATED: 13-JAN-1999, 18:24**

MIKE 11

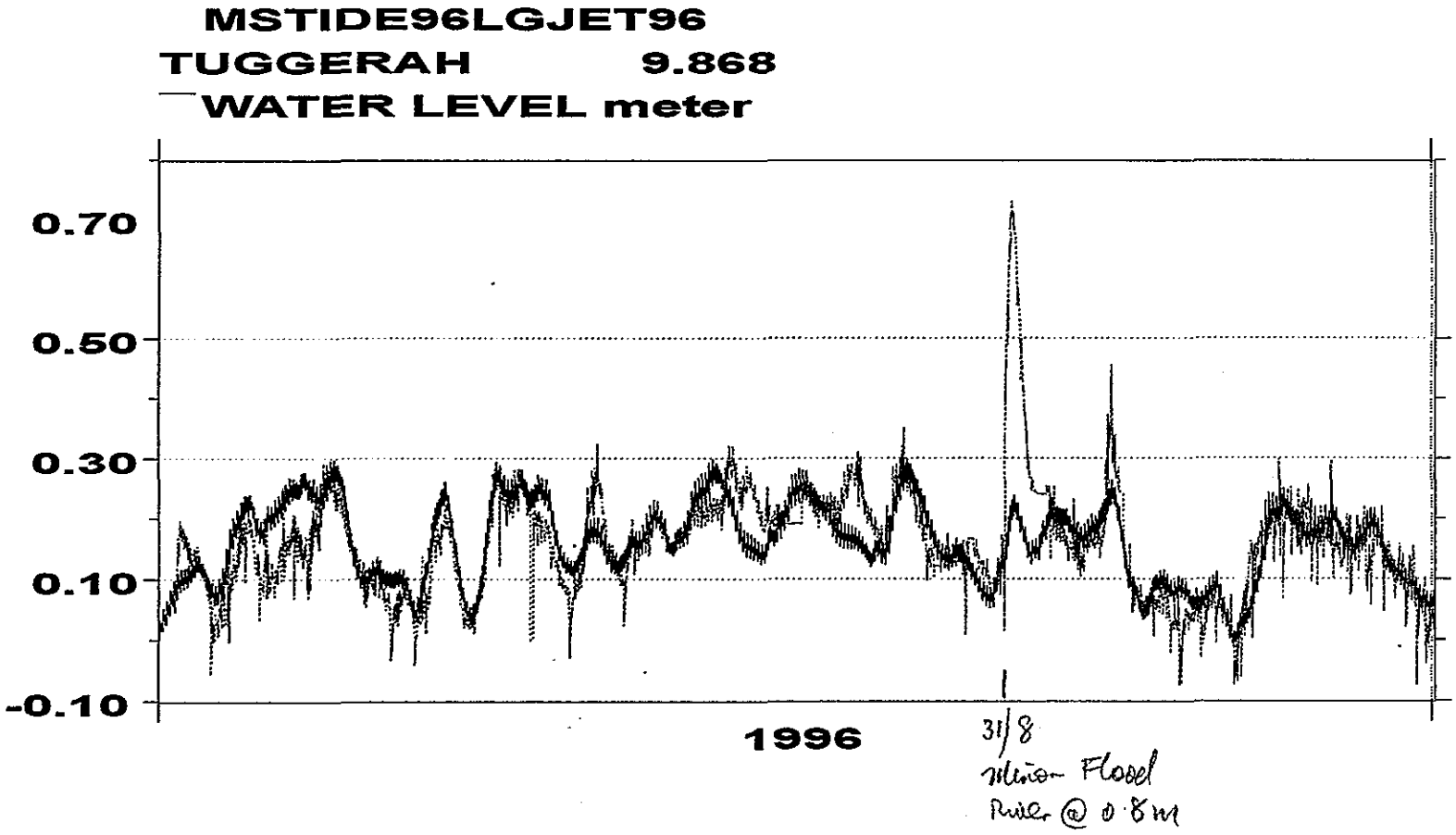
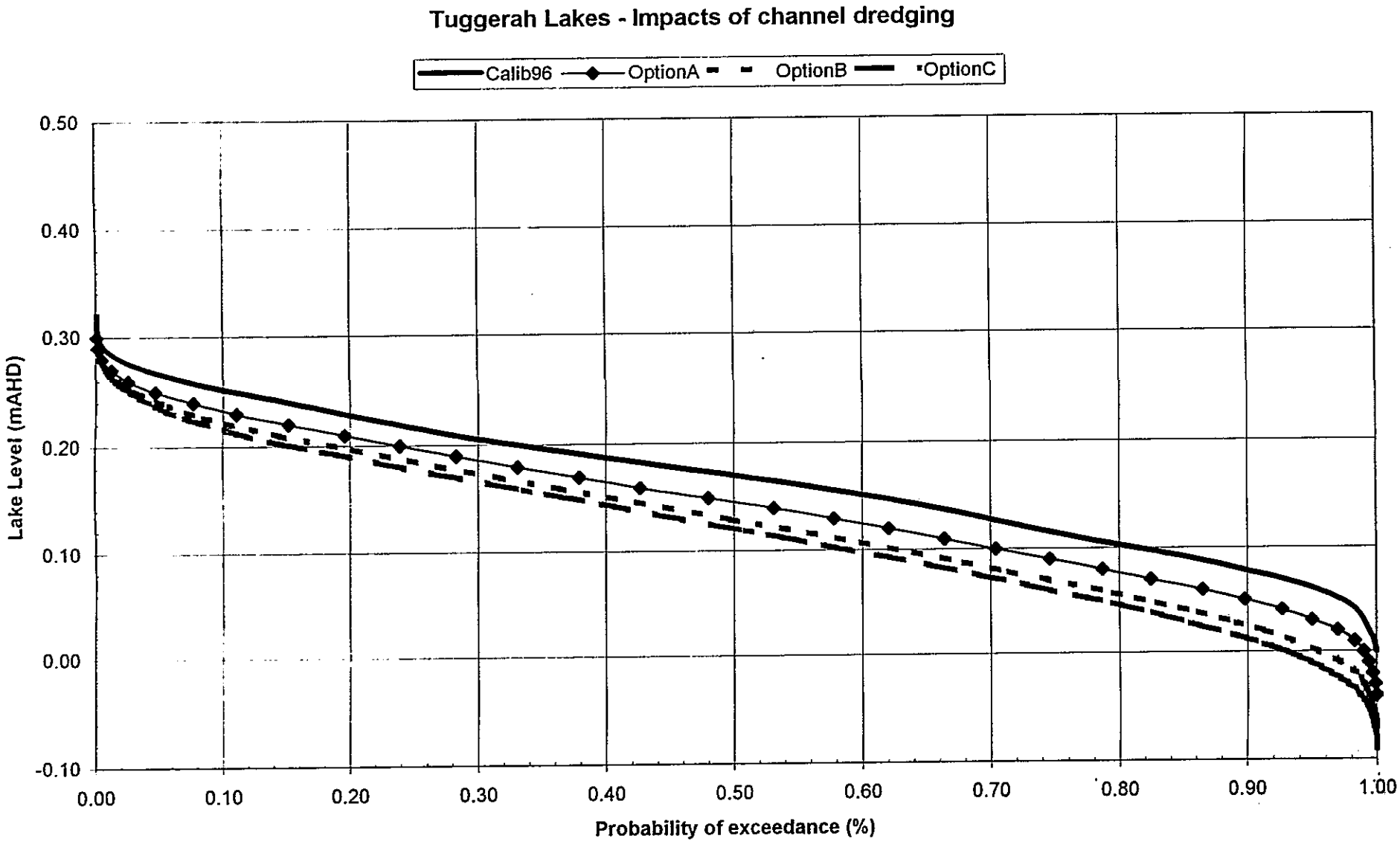


Figure 4
Long Jetty

J1710 Recalibration of Tuggerah Model
Calibration runs for March 1996
14.01.99/KMG

DATA FILE : CALIB96.RDF BOUNDARY FILE: MSTIDE96.BSF
RESULT FILE: CALIB96.RRF CALCULATED: 13-JAN-1999, 18:24

MIKE 11



J1710
10/02/99

Figure 5 Exceedance plot for channel dredging

LAWSON AND TRELOAR PTY LTD

Coastal, Ocean and Water Resources Consulting Engineers

F99-1

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6 May, 1999

Wyong Shire Council
P O Box 20
Wyong
NSW 2259

Our Ref: J1710/L7409
Attn: Mr Tom Wallace

Dear Sirs,

RE: Tuggerah Lakes Tidal Modelling
1993 Verification and Entrance Dredging Impacts

1993 Verification/Modelling

Following our letter (J1710/L7340), Council's letter of March 4, 1999 and our telephone conversation (Wallace/Treloar) in early April about the File Note Council prepared as a result of the review of the modelling results undertaken by Patterson Britton & Partners, we now report on the outcome of additional tidal modelling undertaken using Council's January, 1993 entrance survey.

As part of this work two additional model cross sections were included in the model layout, both within the entrance, see Diagram C, attached. The 1993 survey contour plan was used to prepare all applicable cross sections for this work. A similar exercise was undertaken using the 1996 survey data to improve that model.

The first modelling task was to re-examine the 1996 calibration with the change to The Entrance region included. Figure 1 provides this result which is believed to be a good outcome at all three locations – Toukley, Long Jetty and The Entrance water level recorders. In these figures measured data is represented by the reddish lines.

The model developed and calibrated for the 1996 entrance conditions was then verified for the 1993 entrance conditions. Only limited water level data was available for the 1993 verification. Measured ocean water level data (Sydney, prepared by Manly Hydraulics Laboratory for Council) for January was used as boundary data for

the model. Recorded water level data from Long Jetty was also available for this period.

Figure 2 provides a comparison between modelled and measured data at Long Jetty. The overall agreement is good, but the observed data shows some unexplained spikes. Positive spikes may be associated with rainfall events, whereas negative spikes may be associated with the inverse barometer effect caused by higher atmospheric pressure, or coastal trapped waves. However, the boundary data should include these changes and the Long Jetty negative water level changes have durations that are too short for these phenomena. Therefore they are most likely data errors.

Table 1 presents the results of analyses of model results based on a one year simulation for 1993. Comparison with Table 1 of (J1710/L7340) shows the much reduced 1993 mean tidal range (0.016m) compared with the 1996 mean tidal range (0.026m). However, the 1993 based Options A, B and C mean tidal ranges are greater than those determined for 1996 based Options A, B and C, possibly as a result of the different bed friction structures and ocean tides used in the original 1996 model calibration. Note that the range of lake levels is now smaller. These lake level variations are dominated by the spring–neap tidal cycle (tidal pumping), rather than the semi–diurnal tide range. Comparison between Figures 1 and 2 shows bigger cyclical (tidal pumping) changes in lake level in 1996. Note these simulations (1993) are based on predicted ocean tides and none of the met–ocean variations is included. The previous 1996 investigations were based on a measured tide at Sydney.

Table 1 *Impacts of dredging the entrance channel*

	Lake Level (m AHD)			
	Mean	**Minimum**	**Maximum**	**Mean Tidal Range (m)**
Existing (Verif93)	0.14	0.00	0.23	0.016
Option A	0.09	–0.02	0.23	0.041
Option B	0.09	–0.04	0.24	0.060
Option C	0.08	–0.05	0.26	0.072

In Figure 3 the probabilities of exceedance of lake level have been presented for the existing (1993) and the three proposed dredging options. This result shows that the largest change in lake levels arises between the existing to Option A works. Note that at low lake levels (≤0.1m AHD), the sequence is existing, Option A, B and C, whereas for lake levels ≥0.12m AHD, this changes to existing, Option C, B and A. This characteristic can also be seen in the previous 1996 results (Figure 5 of J1710/L7340), but with the change occurring at a lower probability of exceedance. We believe that this situation arises because there are two tidal processes affecting tidal levels in the lakes. They are the propagation of the semi–diurnal tides into the lakes and the spring–neap cycle of tide range causing 'tidal pumping'. In a fully open

entrance there would be no 'tidal pumping', but the full semi–diurnal range of ocean tide would be experienced. For an entrance which is nearly fully closed, 'tidal pumping' may be small, but much larger than the semi–diurnal tide range. In between these two extreme entrance cases, the character and range of water levels experienced by the inter–tidal flats varies significantly. Changes to the 'tidal pumping' magnitude are not monotonically dependent on entrance area. Entrance area is not the only measure, flood and ebb water depths are important also. This is demonstrated by comparing the 1993 and 1996 results. Note that it may be important to consider probability of exceedance and event durations, or persistence of water level.

Other Issues

Figure 4 provides comparisons amongst::–

1. 1993 entrance + predicted 1993 tides
2. 1996 entrance + predicted 1993 tides
3. 1996 entrance + 1996 measured Sydney tides.

These results provide a basis for comparisons between the 1993 and 1996 entrances using a common ocean tide and the influence of tide for a given entrance – 1996. These comparisons are complex near low tide. Note that variation in ocean tides may have a bigger influence on lake level than changes in entrance geometry, within the range of entrances tested.

File Note Comments

These responses are to be read in conjunction with Council's File Note.

1. We believe that this is the case.

2. We await an opportunity for Council to obtain field data

3. This issue has been addressed in the re–calibration and the importance of the bridge is less than bed friction/entry losses.

4, 5, 6. No comment needed.

7. It is understood that proposed ferry traffic would not proceed beyond the bridge. Should additional scour occur, the model could be used to assess potential impacts

8. Reported herein

9. This is true, particularly for the nearshore inter–tidal areas. It is understood that Council is presently (1999) surveying these areas. The model results show, for example, that at present (1993), a water level of 0.1m AHD would be exceeded for

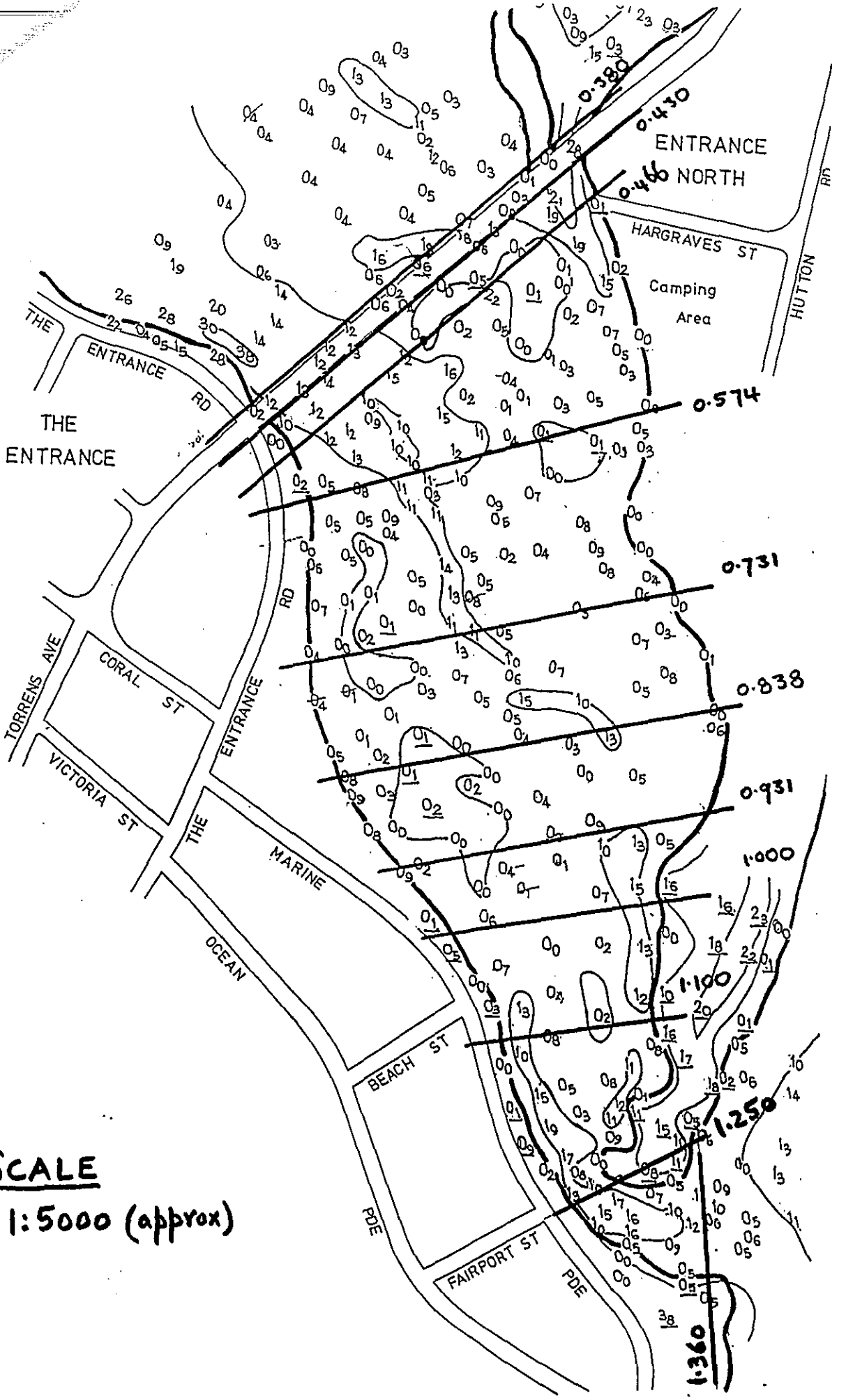
about 85% of the time. Should the entrance be dredged according to Options A, B or C, then this level will be exceeded for only about 40% to 50% of the time. Some change in duration of inundation would occur also. This change would be caused mainly by the change in spring–neap tidal pumping.

10. Some local, but not general instability would occur.

We hope that this information is helpful, and would be pleased to discuss these issues with you should you wish.

Yours faithfully,
Lawson and Treloar Pty Ltd

P D Treloar

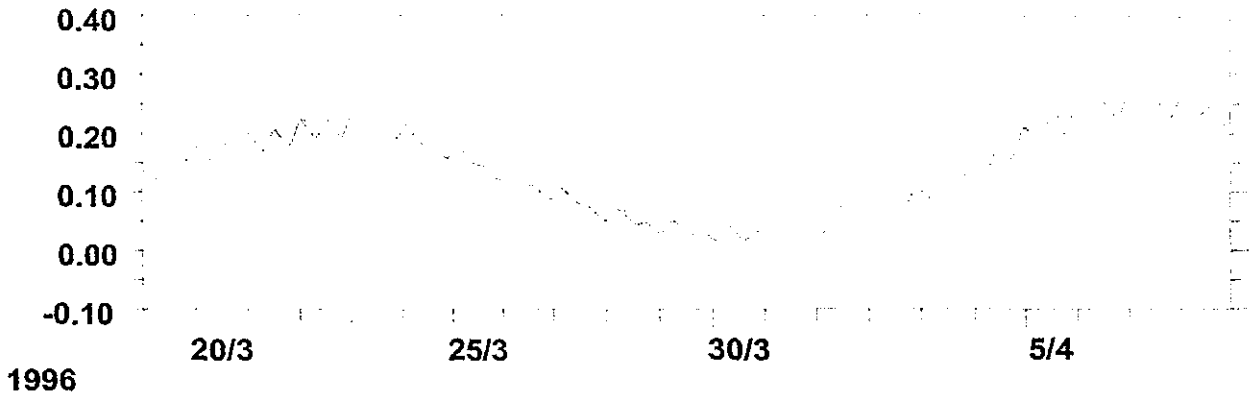


SCALE

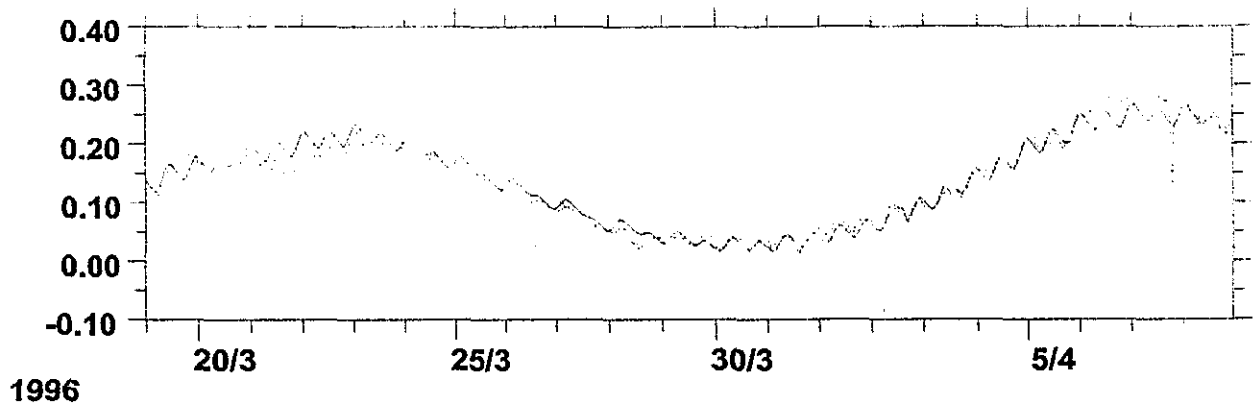
1:5000 (approx)

DIAGRAM 'C'

MSTIDE96TOUK96
TUGGERAH 0.300
WATER LEVEL meter



MSTIDE96LGJET96
TUGGERAH 9.868
WATER LEVEL meter



MAR96 TIDE7411
ENTRANCE 0.360
WATER LEVEL meter

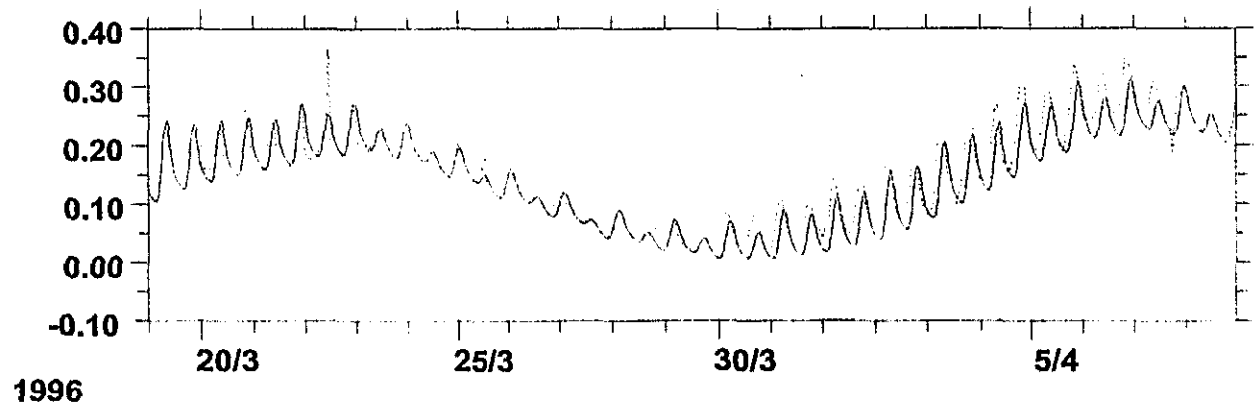


Figure 1 Calibration Results	J1710-Recalibration of Tuggerah Lakes Model New XS at Entrance, Modified Roughness 1996 Tide (HUR-22/4/99)

DATA FILE : CALIB96A.RDF
RESULT FILE HUR4-96.RRF

BOUNDARY FILE MSTIDE96.BSF
CALCULATED 09-APR-1999, 13:01

MIKE 11
J1710-SQC-KMG

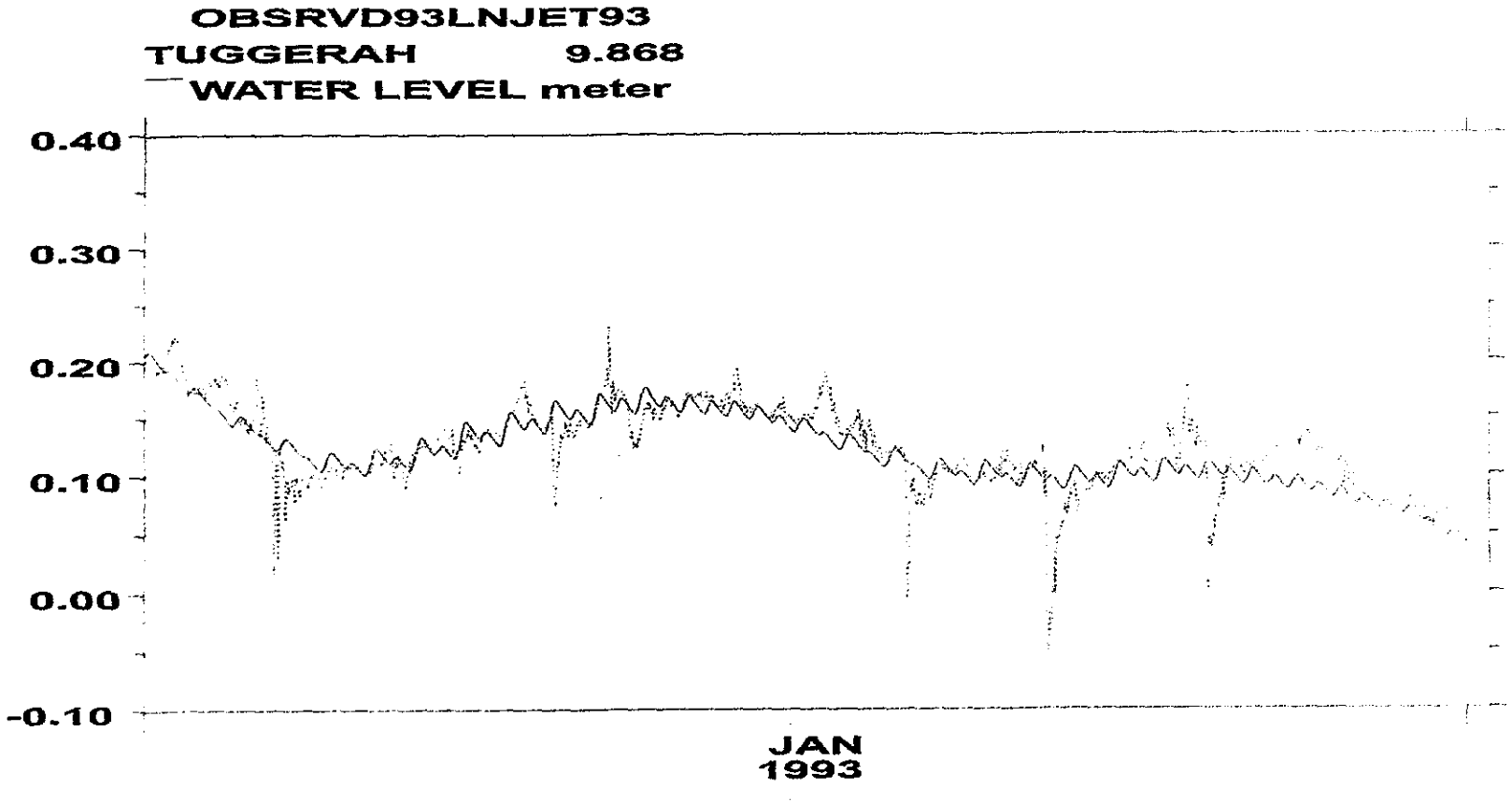


Figure 2
Verification Results

J1710-Recalibration of Tuggerah Lakes Model
Verification of the Model, New XS at Entrance
1993 Tide (HUR-22/4/99)

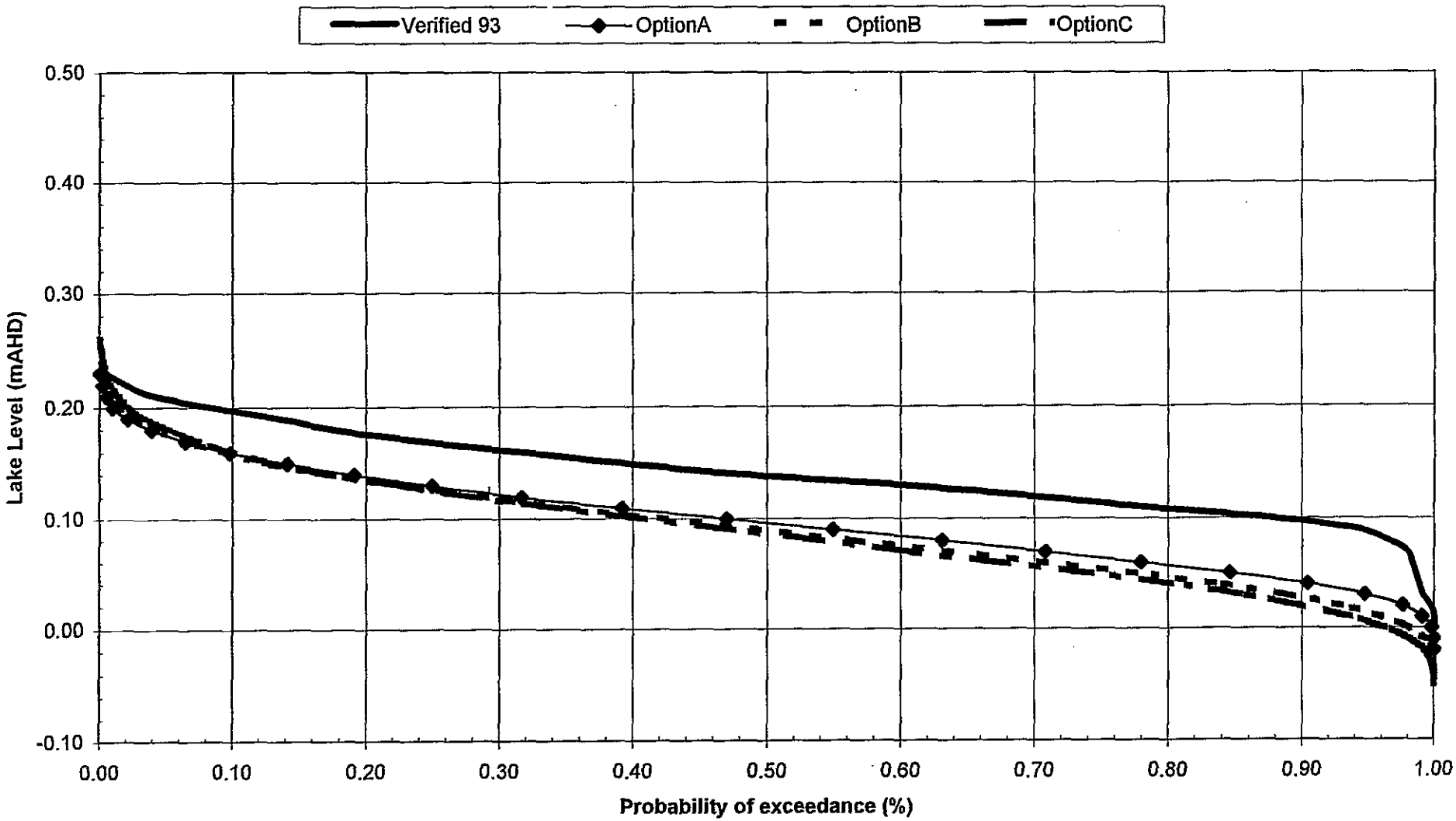
DATA FILE : CALIB93A.RDF
RESULT FILEHUR5-93.RRF

BOUNDARY FILE93_OBS.BSF
CALCULATED22-APR-1999, 10:21

MIKE 11

J1710-SQC-KMG

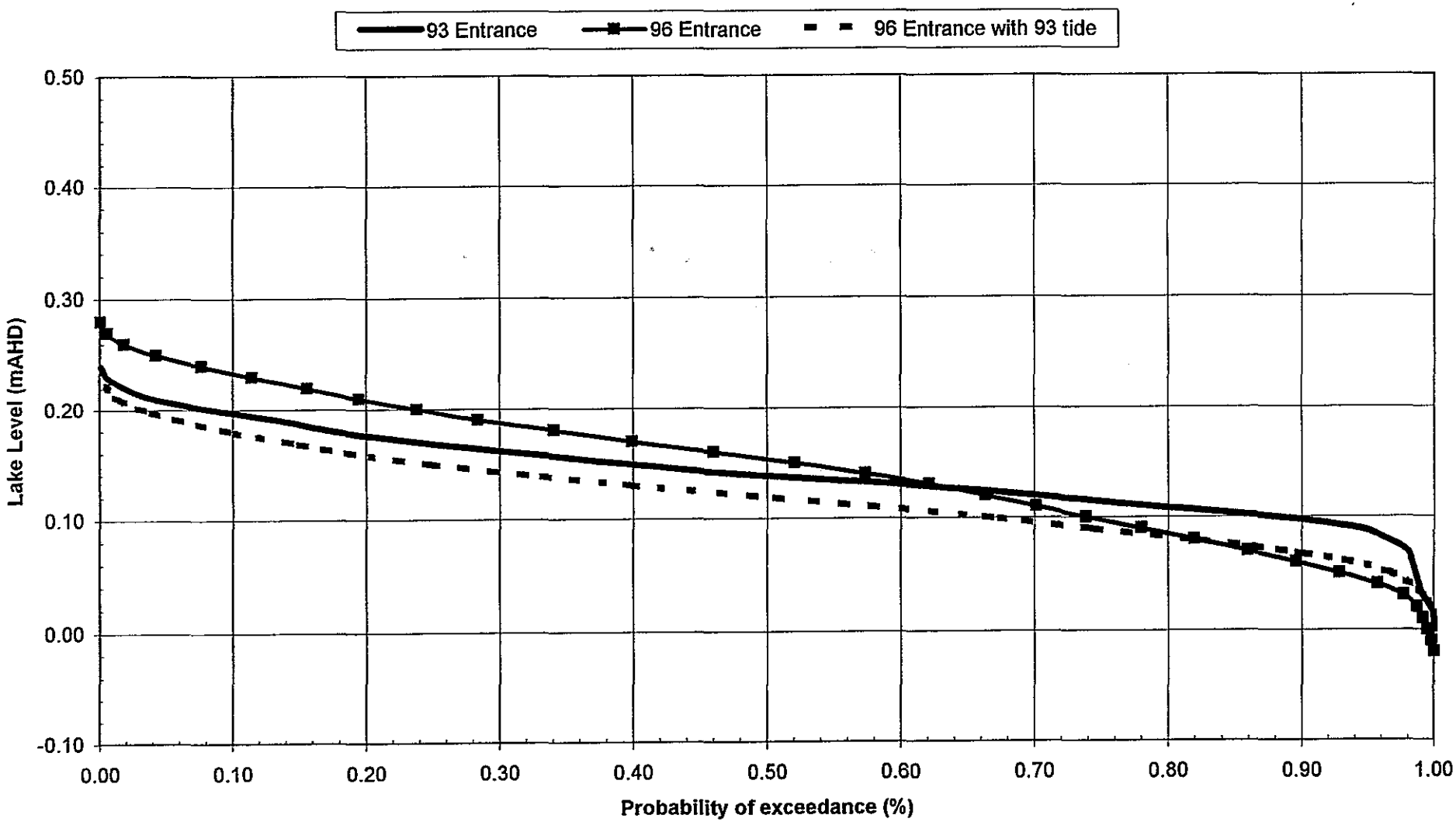
Tuggerah Lakes - Impacts of channel dredging



J1710
07/05/99

Exceedance plot for channel dredging
Figure 3

Tuggerah Lakes - Comparison of Tidal Boundary and Entrance Conditions



J1710
06/05/99

Exceedance Plot for Tidal and Entrance Conditions for 1993 and 1996
Figure 4