



WILDERNESS REPORT NO.1

**EVALUATION OF PROTOTYPE DATA
AND THE APPLICATION OF A NUMERICAL
MODEL TO THE WILDERNESS LAKES AND
TOUWS RIVER FLOODPLAIN**

submitted to

**THE COASTAL LAKES WORKING GROUP
INLAND WATER ECOSYSTEMS
and
THE NATIONAL TRANSPORT COMMISSION**

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NATIONAL RESEARCH INSTITUTE FOR OCEANOLOGY
COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH

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NATIONAL RESEARCH INSTITUTE FOR OCEANOLOGY
COASTAL ENGINEERING AND HYDRAULICS DIVISION

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SCOPE

During 1978 the Coastal Engineering and Hydraulics Division (CEHD) of NRIO was asked by the Co-operative Scientific Programme (CSP) to contribute to the research study of the Touws River floodplain and Wilderness Lakes being conducted by the Coastal Lakes Working Group within the Inland Water Ecosystems Section of the National Programme for Environmental Sciences.

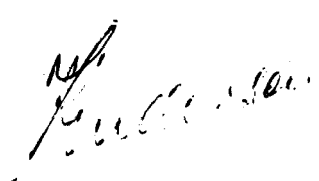
This overall study was of interest to the National Transport Commission (NTC) because the proposed national road would cross the flood plain of the Serpentine. NTC wished to ensure the co-operative study be sufficiently advanced so that consideration could be given to their proposal and hence avoid possible delays at a later date if certain aspects of the multi-disciplinary study were neglected.

The CEHD contribution to the study comprised the mathematical modelling of the flow in the Touws River and Wilderness Lakes System; the work was sponsored by the National Transport Commission.

The study was commenced during 1979, when the area was surveyed and existing data on river flow and water levels were obtained from the Department of Water Affairs for analysis. A mathematical model of the flow system was developed and during 1980 was calibrated against a number of flood events for which prototype data were available. The calibration was limited to flood events with the estuary mouth closed because to date no reliable data exist on flow in the estuary when the mouth had been opened either naturally or artificially.

This report describes interpretation of the field data, the initial calibration of the numerical model, tests to simulate the influence of dredging on the hydraulics of the lake system, and the prediction of flood lines for various flood currents.

The work described was done by Mr. W.A.M. Botes and Mrs. W.J. Kuyler of this Institute's Coastal Engineering and Hydraulics Division under the supervision of Mr. K.S. Russell, head of the Division.


F.P. ANDERSON
DIRECTOR

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1. GENERAL

The lake system comprising Rondevlei, Langvlei and Eilandvlei, together with Wilderness Lagoon and the land bordering the water areas are under the control of, and are managed by, the Lakes Management Board (LMB). The Management Board controls, to some extent, the inland water level by opening the estuary mouth artificially. By this means high water levels, beneficial for recreation, is maintained in the lagoon and lakes. This must, however, be balanced against potential flooding of the areas adjacent to the lagoon in the event of flood discharge, particularly as flood discharge from the Touws River has a very short peak period of about six hours, and the estuary has a limited volume for retention of the flood discharge.

Various physical modifications of the system, that is, improvement of the interconnections between the lakes, etc., would influence the flow conditions in the system and would have direct consequences on the overall ecology of the system. A hydrodynamic numerical model, developed by NRIO, has been used to simulate the flow in the lake system and to study the influence of various physical modifications on the flow regime. The results of these studies will form a basis for further water-quality and ecological considerations.

The project comprised

- (i) a survey of the lake area,
- (ii) the collection of prototype data including data on water levels and river flows, and
- (iii) the development, calibration and initial verification of a one-dimensional explicit numerical model.

The calibration of the model and simulations of prototype flood events were limited to 'closed-mouth' conditions. Prototype data obtained during periods when the mouth was opened to the sea were, at the time, insufficient for calibration of the model.

Prototype data of the Touws River flow, the water levels at Wilderness and in the Bo-Langvlei, Onder-Langvlei and Rondevlei were obtained from the Department of Water Affairs. Three sets of data were selected, of which one was used for the calibration of the numerical model.

For the sake of completeness the other two data sets have been included in this report; these will be used for further model simulations as soon as additional information relating to the rainfall distribution in the catchment area and groundwater flow is obtained.

The effect on the system of dredging the Serpentine, the connection between Onder-Langvlei and Bo-Langvlei, and Rondevlei and various combinations of these were then compared with the existing situation using the same input conditions as had been used for calibration of the model. These tests indicated clearly the obstruction to the flow caused by the connection between Onder-Langvlei and Bo-Langvlei. Dredging of the Serpentine did not significantly improve the existing situation.

Similar tests were done for the various flood discharges predicted by the Hydrological Research Unit of Rhodes University. These tests provided the flood lines for the predicted flood discharges with the estuary mouth closed.

The most practical means for reducing the flood level will be by maintaining the sand sill at the estuary mouth which will be overtopped and then scoured during floods.

Tests were done on a system with a rigid, non-scouring, sill at the mouth. This will be a severe condition when compared to that in which there is a sand sill which would be scoured immediately during overflow and thus increase the discharge.

Tests were also carried out with a schematised scouring sill, but more information will have to be obtained about mouth size, grain size of sediment, rate of scour, etc. to enable the mouth area to be modelled more exactly and simulation of the model to be verified. Existing prototype information does not contain sufficient data for this verification and it is essential that these data be obtained when the estuary is opened to the sea.

2. PROTOTYPE DATA

2.1. Survey

An accurate survey of the area which will be inundated during maximum flood was required to 'construct' the model. The survey, Figure 1b, included depth profiles of the lakes and lagoon, together with cross-sections of the river, the Serpentine and the connections between the lakes, extended to the highest predicted water level during flood. This survey was carried out by Ninham Shand and Partners assisted by NRIO staff during November 1979. In addition, permanent beacons were established at the mouth of the Touws River to provide controls for monitoring future openings of the river mouth. A listing of the co-ordinates and levels obtained from the survey is available from NRIO.

Cross-sections of the lakes, Serpentine, Touws River and the connection channels are shown in Figures 2.1a-e. The cross-sectional areas and hydraulic radii required for the model computation are listed in Tables I/1 and I/2. The plan areas, used for computation of the storage volume at each section are given in Table I/3.

The volume of water contained in the lakes and lagoon with increased water level is given in Table II and plotted in Figure 2.2.

2.2. Water-level Recordings

Water-levels were recorded by the Department of Water Affairs from March 1977 at Wilderness, Onder-Langvlei, Bo-Langvlei and Rondevlei. A CSIR water-level recorder was installed at the end of Wilderness lagoon in August 1979. The positions of the recorders are indicated on the layout of Wilderness in Figure 1b.

Water-levels from records at the Department of Water Affairs were related to the zero of the gauge plate for the specific installation. The following corrections are required to convert the records to mean sea level (MSL).

Wilderness	Recorder K3L04	+ 1,13 m
Onder-Langvlei	K3L03	+ 1,10 m
Bo-Langvlei	K3L02	+ 0,96 m
Rondevlei	K3L01	+ 0,63 m

This means that a reading of 0,50 m recorded at Wilderness (K3L04) will correspond to + 1,63 m MSL.

Two sets of prototype data which corresponded to flood events and during which the recorders were operational, were selected from the records:

The first data set contains two flood events with peak flows on 2 November 1978 and 2 January 1979. The two data sets are from 24 October 1978 to 6 February 1979 (Table III/1) and 17 July 1979 to 20 August 1979 (Table III/2).

The data retrieval during these selected periods is indicated on bar charts in Figure 3.

Water levels at all stations, corrected to MSL, for the two selected periods are given in Tables III/1 and III/2 and in Figures 4.1a-c and 4.2.

2.3. Touws River Flow Data

The discharge of the Touws River was recorded from April 1969 by means of a water-level recorder. The Touws River discharge is illustrated in a histogram (Figure 6) of the average daily discharge from 1968 to 1975, obtained from the Department of Water Affairs. Selected data are indicated on the bar charts in Figure 3.

Corrected flows for the selected periods are given in Tables III/1 and III/2. The discharge hydrograms for a number of flood events, including the periods selected for model calibration are shown in Figure 5. No information on the discharges of the Duiwe River and Bo-Langvleispruit is available.

2.4. Touws River: Opening and Closing of the Estuary Mouth

Information on the opening and closing of the river mouth obtained from the Lakes Area Development Board is summarised in Table IV. During the 15-year period from September 1964 to September 1979, the mouth was open on 21 distinct occasions, remaining open for 970 days during the 10-year period, which is equivalent to being open for 27 per cent of the time.

The periods during which the mouth was open have also been compared with the river discharge histogram. Figure 6 shows breakthrough of the mouth follows periods of high discharge.

The duration for which the mouth remained open is also shown in Figure 7. During the earlier period 1964 to 1975, the mouth remained open on average for some 50 days after breakthrough; since 1975 this average has decreased to 28 days.

3. EVALUATION OF PROTOTYPE DATA

3.1. Water-level Recordings

Water-level histories of periods April to June 1977, October 1978 to January 1979 and July to August 1979 are in Figures 4.1a-c and 4.2, respectively.

Figure 4.1a indicates a sudden rise in water levels for all the lakes during a flood, but after the opening of the Touws River mouth the levels of two upper lakes, Bo-Langvlei and Rondevlei took 45 days (see Figure 4.1b) to reach the level of Wilderness lake and Onder-Langvlei. This indicates that there are no proper connections between Bo-Langvlei and Onder-Langvlei during periods when the water level drops below about 1,6 m.

This is again illustrated in Figure 4.1.c. The initial water level before the flood of the Touws River is 1,4 m, the water level in the upper lakes rises very slowly because of the poor connection between Onder-Langvlei and Bo-Langvlei.

3.2. River Flows and the Response of the Lake System

Only data on the Touws River discharges are available. However, from Figures 8a and 8b it is clear that minor rivers also have influence on the fluctuations in water-levels of the lakes.

In order to determine the response of the lake system to certain river discharges the cumulative increase in volume of the lakes was compared with cumulative discharge volumes of the available Touws River flows. The values are given in Tables V/1 and V/2 and graphical representations of the volume increase and total river discharges are given in Figures 8a and 8b.

Figure 8a indicates a volume increase of the lakes of 0,7 million cubic metres more than the total discharge from Touws River. The same tendency can be seen in Figure 8b but the difference is even greater, that is, 1,4 million cubic metre.

As mentioned in Section 2,3, this could be the result of the unknown flows of Duiwe River, Bo-Langvlei Spruit and of rainfall.

Floods for Duiwe River and Bo-Langvlei Spruit can be simulated to compensate for the difference in total volumes by using the results in Table V/1 and Figure 8a as well as the flood hydrographs in Chapter 4. Total discharges of Touws River, Duiwe River and Bo-Langvlei Spruit were calculated for a 1 in 5 year flood from the flood hydrographs. From this it was determined that the total discharge of Duiwe River and Bo-Langvlei Spruit is 19 per cent of the total discharge of Touws River. From these values schematic flows for the minor rivers could be simulated to calibrate the numerical model.

4. ESTIMATED FLOOD HYDROGRAPHS BY A.H.M. GÖRGENS

4.1. Background

The Hydrological Research Unit's brief as formulated at the Eighth Meeting of the Working Group for Coastal Lakes on 13 September 1979, comprised providing the National Research Institute for Oceanology (NRIO) with flood hydrographs representing the 5-, 10-, 20-, 50- and 100-year return-period events in the major streams that flow into the Wilderness Lakes. These hydrographs would be used as inputs to the NRIO hydraulic model of the Lakes system.

This type of objective can usually be attained by two methods:

- (a) Synthetic generation of the flood hydrographs using a suitable engineering method, e.g. the unit hydrograph technique, which require synthesized rainstorms of the required return periods as input data.
- (b) Simulation modelling of the rainfall-runoff processes in a catchment using observed historical rainfall and evaporation records as input data and producing reconstructed historical flow records. Return periods can then be awarded to the most extreme events in the reconstructed record.

The Unit followed both approaches in the Wilderness study.

4.2. Synthetic Flood Hydrographs

Flood hydrographs representing the 5-, 10-, 20- and 50-year events in the three major streams flowing into the lakes were presented in *Special Report 1/79* (Appendix A1) dated September 1979. These hydrographs were generated by the unit graph technique, using *regional* depth-duration-frequency rainfall data and regional unit hydrographs. Suites or 'families' of 50- and 100-year flood hydrographs for the above streams were subsequently generated using the recently innovated 'run hydrograph' technique which, also used regional rainfall data. These were reported on in *Special Report 1/80*, (Appendix A2) dated September 1980.

4.3. Rainfall-runoff Modelling

4.3.1. Data base

The only available hydrological data base for the region is that which is extractable from the national networks of the Department of Water Affairs, Forestry and Environmental Conservation (DWAFFEC) and of the Weather Bureau. The following table summarises the state of this data base as it has been processed by the Unit:

Data type	Number of gauging sites	Period available	Distribution	Quality of data
Daily flows	9	9-20 yrs.	1. All major streams	1. Many high flow periods unrecorded because weir capacities inadequate 2. Recent years' records not worked up yet by DWAFFEC 3. Outdated rating tables
Hourly flows	9	9-20 yrs.	1. All major streams	ditto
Daily rainfalls	26	20-60 yrs.	1. Very few in high rainfall head-water areas 2. Very few in gauged portions of catchments	1. Many missing record periods 2. Adjacent gauges anomalous
Hourly rainfalls (auto-graphic)	7	1. 2-10 yrs. 2. Six of these closed down since 1977	1. Very poor	1. High % of charts show no recognizable trace 2. Anomalies between adjacent autographic and adjacent daily gauges 3. Many charts unreadable
Daily pan evaporations	4	2-6 yrs.	1. None inside gauged catchments 2. All sites near the coast	1. Many missing record periods

4.3.2. Modelling

Modelling tests have so far been concentrated on the Touws River and Diep River catchments. A modified version of the continuous rainfall-runoff model developed by Dr. W.V. Pitman of the HRU at the University of the Witwatersrand, using daily input data, has been calibrated (optimised) against the recorded daily flows in these two streams. Furthermore, a modified version of the single-event 'U.K. Flood Studies Report' model, using hourly input data, was also calibrated against the recorded hourly flows in the Diep River for a number of storms.

The results of both these modelling attempts have been disappointingly ambiguous and indicate the serious deficiencies inherent in the data base. This has led to a complete reappraisal of the data base, which is in progress at present. Negotiations with DWAFEC are also afoot to improve the autographic rain gauge distribution in the area, as well as to update the historical flow records. Without these improvements, the success of a rainfall-runoff modelling approach to the generation of representative flood hydrographs for the Wilderness streams remains in the balance.

5. MODEL CALIBRATION

5.1. General

The preliminary calibration of the model was made with the Touws River mouth assumed to be closed because of the lack of sufficient information on the closing and opening of the river mouth.

Two sets of prototype data in which it was assumed that the mouth was closed were available as discussed in Chapter 3. The data related to Touws River discharges and water level histories of Wilderness, Onder-Langvlei, Bo-Langvlei and Rondevlei. Flows in the Duiwe River and Bo-Langvlei Spruit were schematized for one set of prototype data (January 1979) but for other periods this was not possible because of local circumstances such as local precipitation, ground water flow, minor rivulets and evaporation.

5.2. The Numerical Model

The computational scheme used for the Wilderness study was based upon a finite-difference scheme. The water motion was assumed to be one-dimensional and the calculation was done by an explicit method.

The equation of motion at time t is

$$\frac{\partial h}{\partial x} = \frac{1}{gA} \frac{\partial Q}{\partial t} - \frac{1Q|Q}{C^2 A^2 R} + \frac{2bQ}{gA^2} \frac{\partial h}{\partial t} + \frac{Wx}{\rho g R} \quad \dots (1)$$

where:

- h = water level (m)
- x = distance (positive upstream) (m)
- Q = discharge (m^3/s)
- g = acceleration due to gravity (m/s^2)
- A = cross-sectional area (m^2)
- b = stream width (m)
- t = time (s)
- C = Chezy coefficient
- R = hydraulic radius (m)

- W_x = wind factor = $\tau_w \cos \theta$
 τ_w = wind shear stress = $\rho_{\text{air}} C_D V_{10}^2$
 ρ_{air} = mass density of air (kg/m^3)
 C_D = drag coefficient = $0,5\sqrt{V_{10}} * 10^{-3}$
 V_{10} = wind velocity, 10 m above water surface (m/s)
 θ = angle between wind direction and channel axis.

The equation for the continuity of flow is:

$$\frac{\partial Q}{\partial x} = -b \frac{\partial h}{\partial t} \quad \dots (2)$$

All differential quotients in equations 1 and 2 can be reformed to difference quotients and substituted in 1 and 2 as, for example:

$$\frac{\partial h}{\partial x} = \frac{h(x+\Delta x, t) - h(x-\Delta x, t)}{2\Delta x}$$

$$\frac{\partial h}{\partial t} = \frac{h(x, t+\Delta t) - h(x, t-\Delta t)}{2\Delta t}$$

$$\frac{\partial Q}{\partial x} = \frac{Q(x+\Delta x, t) - Q(x-\Delta x, t)}{2\Delta x}$$

$$\frac{\partial Q}{\partial t} = \frac{Q(x, t+\Delta t) - Q(x, t-\Delta t)}{2\Delta t}$$

A new set of equations can be obtained which can be used to compute water levels and flows at different positions and time levels.

In an explicit method the unknown values (values of h and Q at certain time levels) are expressed directly in terms of known values (values of h and Q at previous time levels).

When the Touws River mouth was closed, three boundary conditions were used, that is, the discharges of the Touws River, Duiwe River and Bo-Langvlei Spruit which were set at the appropriate sections for the length of the test run.

The computational time step, Δt , is controlled by the smallest section length and a time step of 60 s was used for the computation.

Program listings of the main program as well as of the secondary programs (plot routines) are given in Appendix B.

5.3. Hydrographical Data

A general layout of the lake system is shown in Figure 1b. Cross-sections are indicated in the figure and schematic drawings of the sections are given in Figures 2.1a-e. The effective flow areas were schematized and the data of the areas and the corresponding hydraulic radii are given in Tables I/1 and I/2, respectively.

The plane areas used for the calculation of the storage volumes are shown in Table I/3.

Distances between the cross-sections are indicated in Figure 1.

5.4. Resistance

Two friction equations were used for the lake system.

The standard Chezy equation

$$C_1 = 37,5 + 18,0 \log R$$

was used for all river and lake sections.

Because of the high friction in the Serpentine and other connections due to small channel sections and dense vegetation on the flood planes, the standard equation was adapted to

$$C_2 = 25,0 + 50,0 \log R$$

for the connections between the lakes.

The Chezy coefficients for these two cases are plotted in Figure 9 for increasing hydraulic radius R . In the computation the friction term is given as $\frac{|Q|Q}{C^2 A^2 R}$. As can be seen from Figure 9, for values of $R > 2$ the

effect of friction in the channel connections and for the standard formulation tend to the same value. Thus, when the connections are dredged, as in the later tests, the effect of friction term adjusts automatically without there being any need to change the coefficient through the input to the program.

5.5. Prototype Data

Prototype data for the period 1 January 1978 to 15 January 1979 were used for the calibration of the numerical model. This period was one of the two for which data were available which included water-level histories of Wilderness and the three lakes, Touws River flood, and with the Touws River mouth closed. Water level recordings are given in Figure 4.1c. River floods are shown in Figure 5.

When the total increase in volume for the lakes are compared with the total discharge of Touws River (Figure 8a) it is clear that there must have been additional inflows from Duiwe River, Bo-Langvlei Spruit, other minor rivulets and possibly local precipitation.

The discharges of Duiwe River and Bo-Langvlei Spruit were approximately 19 per cent of the discharge of Touws River, according to theoretically determined flood hydrographs (Hydrological Research Unit, Rhodes University) as described in Appendix A.

Schematic discharges from Duiwe River and the Bo-Langvlei Spruit were determined for the period 1 January 1979 to 15 January 1979 when the maximum discharge for Touws River was 45 cumec. These data (Touws River, Duiwe River and Bo-Langvlei Spruit) were used as an input condition for the calibration of the model.

From Figure 4.1c it is clear that there was a considerable rate of evaporation and ground water flow, because the water levels in the lakes decreased although the mouth was closed. An evaporation rate of 3 mm/day (0,000 208 mm/min) was assumed for the calibration.

Although the second set of prototype data (during July 1979) was used for a model run it could not be used for calibration because the volume of the lakes increased by $1,4 \times 10^6 \text{ m}^3$ cubic water more than the total discharge of Touws River (Figure 8b).

5.6. Calibration Results

The prototype data for January 1979 which were used as input conditions for the model and the model results are given in Figure 10a. The agreement is extremely good and it can be assumed that the model was calibrated for these prototype conditions.

	Water levels (m)				Time for all lakes to come to the same level
	Wilderness	Onder-Langvlei	Bo-Langvlei	Rondevlei	
Prototype	2,13	1,92	1,63	1,63	370 hours
Model	2,09	1,90	1,62	1,63	350 hours

The prototype and model results for the period July 1979 are given in Figure 10b. The lack of agreement can be seen from the final water levels, which indicate a larger increase in volume for the prototype which corresponds to the comparison of total volume increase and total river discharge shown in Figure 8b.

The maximum levels of the model and the prototype in the table below indicate the same tendency.

	Wilderness	Onder-Langvlei	Bo-Langvlei	Rondevlei
Prototype	1,97	1,96	1,89	1,91
Model	1,79	1,75	1,66	1,66

In order to improve available data an attempt will be made to correlate the discharges of the three rivers in the lake system with rainfall records for that area as the precipitation could be varied over the catchments of the different streams.

6. MODEL TESTS WITH THEORETICAL RIVER DISCHARGES

6.1. General

The calibrated model with the Touws River mouth closed was used to determine the flood lines for all parts of the Wilderness Lakes for 1 in 5, 1 in 10, 1 in 20, 1 in 50 and 1 in 100 year floods. The hydrographical data for the model is the same as described in Section 3. Initial water levels of 1,4 m and 1,8 m were used.

6.2. Flood Data

The flood hydrographs for the 1 in 5, 1 in 10, 1 in 20, 1 in 50 and 1 in 100 year floods were determined by the Hydrological Research Unit of Rhodes University for the Touws River, Duiwe River and Bo-Langvlei Spruit, based on the unit graph theory given in Appendix A. (Figures A1a-c).

The 1 in 50 and 1 in 100 year run hydrographs are in Figures A2a-e.

6.3. Results

6.3.1. Unit graph theory

The results of the theoretical floods are given in Figures 11.1a-c for an initial water level of 1,4 m and for initial levels of 1,8 m in Figures 11.2a-c.

Maximum water levels in Wilderness and the lakes for the different floods and initial water levels are given in the table below:

Flood	Initial water levels	Maximum water levels (m)				Final levels
		Wilderness	Onder-Langvlei	Bo-Langvlei	Rondevlei	
1/5 yr	1,4	3,08	2,55	2,01	2,01	2,01
1/10 yr	1,4	3,48	2,84	2,23	2,23	2,21
1/20 yr	1,4	3,72	3,00	2,36	2,36	2,33
1/50 yr	1,4	3,88	3,11	2,47	2,47	2,44
1/100 yr	1,4	4,83	3,57	2,88	2,88	
1/5 yr	1,8	3,22	2,72	2,37	2,37	2,34
1/10 yr	1,8	3,61	2,96	2,56	2,56	2,52
1/20 yr	1,8	3,88	3,11	2,68	2,68	2,65
1/50 yr	1,8	4,01	3,20	2,77	2,77	2,74
1/100 yr	1,8	4,93	3,63	3,16	3,16	

6.3.2. Run hydrographs

The model results of the 1 in 50 and 1 in 100 year run hydrographs are given in Figures 12a-e. Initial water level was 1,4 m.

The peak levels for the Wilderness and lakes for these theoretical floods are given in the table below:

Run hydrograph	Flood	Maximum water levels (m)				Final level
		Wilderness	Onder-Langvlei	Bo-Langvlei	Rondevlei	
No. 1	1 in 50	2,74	2,01	1,69	1,69	1,68
No. 1	1 in 100	2,88	2,08	1,73	1,73	1,71
No. 2	1 in 50	3,36	2,64	2,07	2,07	2,05
No. 2	1 in 100	3,80	2,92	2,27	2,27	2,24
No. 3	1 in 50	3,78	3,10	2,43	2,43	2,40
No. 3	1 in 100	4,40	3,48	2,76	2,76	2,72
No. 4	1 in 50	3,71	3,22	2,59	2,55	2,55
No. 4	1 in 100	4,29	3,59	3,03	3,03	2,99
No. 5	1 in 50	3,27	3,10	2,66	2,66	2,63
No. 5	1 in 100	3,63	3,34	3,10	3,10	3,07

7. INFLUENCE OF DREDGING THE CHANNELS

7.1. Dredging the Serpentine

The existing level in the Serpentine is about 0,0 m most of its length, except for some local areas where siltation has taken place. Tests were therefore made with the existing situation, with the Serpentine at 0,0 m for its entire length and dredged to -1,0 m for its entire length.

The dredging of the serpentine would have little influence on the lake system. The peak water level after a flood at Wilderness would lower but it would have no influence on Onder-Langvlei.

The results of the prototype flood during January 1979 for the original layout and with the Serpentine dredged to 0,0 m to MSL and -1,0 m to MSL are given in the table below and in Figures 13.1 and 13.2.

	Maximum water levels (m)			
	Wilderness	Onder-Langvlei	Bo-Langvlei	Rondevlei
No dredging	2,13	1,92	1,63	1,63
Dredged to 0,0 m	2,04	1,92	1,63	1,63
Dredged to -1,0 m	1,97	1,92	1,63	1,63

The results of the theoretical 1 in 5, 10, 20 and 50 years flood for the original layout and with the Serpentine dredged are given in Figures 13.3a-d to 13.4a-d and the maximum levels in the lakes are indicated in the table below:

	Flood	Maximum water levels (m)			
		Wilderness	Onder-Langvlei	Bo-Langvlei	Rondevlei
No dredging	1/5 yr	3,08	2,55	2,01	2,01
Dredged to 0,0 m	1/5 yr	3,02	2,55	2,01	2,01
Dredged to -1,0 m	1/5 yr	2,97	2,55	2,01	2,01
No dredging	1/10 yr	3,48	2,84	2,23	2,23
Dredged to 0,0 m	1/10 yr	3,43	2,84	2,23	2,23
Dredged to -1,0 m	1/10 yr	3,38	2,84	2,23	2,23
No dredging	1/20 yr	3,72	3,00	2,36	2,36
Dredged to 0,0 m	1/20 yr	3,70	3,01	2,37	2,37
Dredged to -1,0 m	1/20 yr	3,67	3,01	2,37	2,37
No dredging	1/50 yr	3,88	3,11	2,47	2,47
Dredged to 0,0 m	1/50 yr	3,83	3,11	2,47	2,47
Dredged to -1,0 m	1/50 yr	3,81	3,11	2,47	2,47

7.2. Dredging the Channel Between Onder-Langvlei and Bo-Langvlei (Long Channel)

7.2.1. Prototype conditions (January 1979)

The water levels decreased considerably in Onder-Langvlei and the water levels of Onder-Langvlei, Bo-Langvlei and Rondevlei came to the same level within 80 hours instead of 400 hours for the original layout. The results are given in Figure 14.1 and the maximum levels are indicated in the table below:

	Maximum water levels (m)			
	Wilderness	Onder-Langvlei	Bo-Langvlei	Rondevlei
No dredging	2,13	1,92	1,63	1,63
Dredged to 0,0 m	2,13	1,70	1,67	1,67

7.2.2. Theoretical floods

The results are shown in Figures 14.2a-d and the maximum levels are indicated in the table below: (Initial level: 1,4 m)

	Flood	Maximum water levels (m)			
		Wilderness	Onder-Langvlei	Bo-Langvlei	Rondevlei
No dredging	1/5 yr	3,08	2,55	2,01	2,01
Dredged to 0,0 m	1/5 yr	3,08	2,20	2,04	2,04
No dredging	1/10yr	3,48	2,84	2,23	2,23
Dredged to 0,0 m	1/10 yr	3,48	2,44	2,25	2,25
No dredging	1/20 yr	3,72	3,00	2,36	2,36
Dredged to 0,0 m	1/20 yr	3,72	2,58	2,38	2,38
No dredging	1/50 yr	3,88	3,11	2,47	2,47
Dredged to 0,0 m	1/50 yr	3,87	2,68	2,48	2,48

7.3. Dredging the Serpentine to -1,0 m and the Channel Between Onder-Langvlei and Bo-Langvlei to 0,0 m

7.3.1. Prototype conditions (January 1979)

The results are shown in Figure 15.1 and the maximum water levels in the lakes are indicated in the table below:

	Maximum water levels (m)				Time (hours) before all lakes are at the same level
	Wilderness	Onder-Langvlei	Bo-Langvlei	Rondevlei	
No dredging	2,13	1,92	1,63	1,63	
Dredged	1,98	1,73	1,68	1,67	

7.3.2. Theoretical floods

a. Initial level: 1,4 m.

The results of the theoretical 1 in 5, 10, 20, 50 and 100 year floods for the original layout and with the Serpentine dredged to -1,0 m and Long Channel to 0,0 m are shown in Figures 15.2a-e and the maximum water levels are indicated in the table below:

	Flood	Maximum water levels (m)				Time (hours) before all lakes are at the same level
		Wilderness	Onder-Langvlei	Bo-Langvlei	Rondevlei	
No dredging	1/5 yr	3,08	2,55	2,01	2,01	300
Dredged	1/5 yr	2,97	2,21	2,05	2,05	70
No dredging	1/10 yr	3,48	2,84	2,23	2,23	190
Dredged	1/10 yr	3,38	2,44	2,25	2,25	65
No dredging	1/20 yr	3,72	3,00	2,36	2,36	160
Dredged	1/20 yr	3,63	2,57	2,36	2,36	65
No dredging	1/50 yr	3,88	3,11	2,47	2,47	140
Dredged	1/50 yr	3,80	2,68	2,47	2,47	65
No dredging	1/100 yr	4,83	3,57	2,88	2,88	80
Dredged	1/100 yr	4,77	3,10	2,88	2,88	60

b. Initial level: 1,8 m.

The results are shown in Figures 15.3a-e and the maximum water levels are shown in the table below:

	Flood	Maximum water levels (m)				Time (hours) before all lakes are at the same level
		Wilderness	Onder-Langvlei	Bo-Langvlei	Rondevlei	
No dredging	1/5 yr	3,22	2,72	2,37	2,37	130
Dredged	1/5 yr	3,13	2,45	2,37	2,37	50
No dredging	1/10 yr	3,61	2,96	2,56	2,56	100
Dredged	1/10 yr	3,53	2,64	2,56	2,56	55
No dredging	1/20 yr	3,88	3,11	2,68	2,68	90
Dredged	1/20 yr	3,81	2,77	2,68	2,68	55
No dredging	1/50 yr	4,01	3,20	2,77	2,77	80
Dredged	1/50 yr	3,94	2,85	2,77	2,77	55
No dredging	1/100 yr	4,93	3,63	3,16	3,16	60
Dredged	1/100 yr	4,88	3,24	3,16	3,16	50

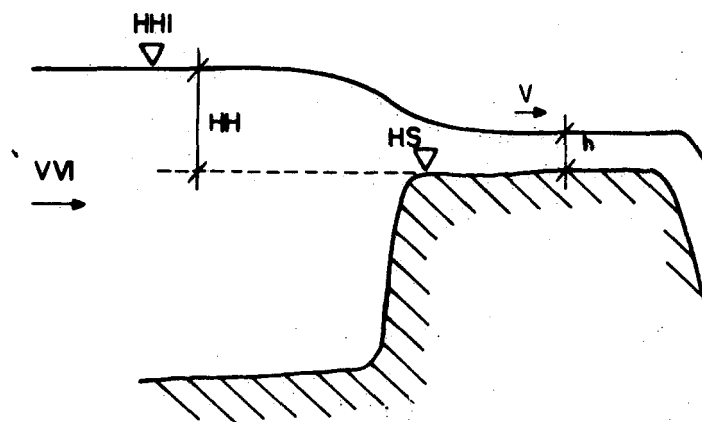
8. TESTS WITH A SILL AT TOUWS RIVER MOUTH

8.1. General

It will be possible to reduce the peak levels in the Wilderness Lagoon by keeping the height of the sill at Touws River mouth constant. This will be easy to maintain by means of levelling pegs. This can be done at any time and it will not be necessary to make a decision during flood conditions about opening the mouth.

Because of the present lack of information about estuary mouth dynamics, the sill was assumed to be rigid, which will represent the worst condition, as scouring will take place as soon as the water starts overflowing.

8.2. Calculation of Flow at the Touws River Mouth With a Constant Level Rigid Sill



Where:

- VV1 = velocity of approach
- HH1 = water level in lagoon (to MSL)
- HH = potential head ($HH = HH1 - HS$)
- HS = height of sill

h = depth at sill
 V = velocity at sill
 B = width of sill
 L = length of sill
 QQ = discharge at sill
 C = Chezy coefficient
 R = hydraulic radius

$$\frac{VV1^2}{2g} + HH = \frac{V^2}{2g} + h + \text{friction head}$$

$$= \frac{V^2}{2g} + h + \frac{V^2 L}{C^2 R}$$

$$V^2 = \left(\frac{VV1^2}{2g} + HH - h \right) / \left(\frac{1}{2g} + \frac{L}{C^2 R} \right)$$

$$V = \left(\left(\frac{VV1^2}{2g} + HH - h \right) / \left(\frac{1}{2g} + \frac{L}{C^2 R} \right) \right)^{\frac{1}{2}} \quad \dots (1)$$

Discharge at sill:

$$QQ = VBh \quad \dots (2)$$

Substitute (1) in (2)

$$\begin{aligned}
 QQ &= B \frac{1}{\left(\frac{1}{2g} + \frac{L}{C^2 R} \right)^{\frac{1}{2}}} \left(\frac{VV1^2}{2g} + HH - h \right)^{\frac{1}{2}} h \\
 &= B \frac{1}{\left(\frac{1}{2g} + \frac{L}{C^2 R} \right)^{\frac{1}{2}}} * \left(\frac{VV1^2 h^2}{2g} + HHh^2 - h^3 \right)^{\frac{1}{2}} \quad \dots (3)
 \end{aligned}$$

for QQ maximum

$$\frac{d}{dh} \left(\frac{VV1^2 h^2}{2g} + HHh^2 - h^3 \right) = 0$$

$$h = \frac{VV1^2}{3g} + \frac{2}{3} HH \quad \dots (4)$$

Substitute (4) in (3)

$$\begin{aligned}
 QQ &= B \left\{ \frac{1}{\left(\frac{1}{2g} + \frac{L}{C^2 R} \right)} \right\} \left\{ \frac{VV1^2}{3g} + \frac{2}{3} HH \right\} \left\{ \frac{VV1^2}{6g} + \frac{1}{3} HH \right\}^{\frac{1}{2}} \dots (5) \\
 &= B \left\{ \frac{2}{\left(\frac{1}{2g} + \frac{L}{C^2 R} \right)} \right\} \left\{ \frac{VV1^2}{6g} + \frac{1}{3} HH \right\}^{\frac{3}{2}}
 \end{aligned}$$

8.3. Results of Tests with a Rigid Sill

8.3.1. Sill: Height = 2,0 m; Width = 30,0 m; Length = 20,0 m

8.3.1.1. Initial level: 1,8 m

The influence of the sill with floods of 1 in 5, 10, 20, 50 and 100 year is shown in Figures 16a-e together with the water levels for the original layout with the Touws River mouth closed.

The maximum water levels in the Wilderness Lagoon, Onder-langvlei, Bo-langvlei and Rondevlei for the above-mentioned conditions are in the table below:

Flood	Layout	Water levels (m)				
		Wilderness	Onder-Langvlei	Bo-Langvlei	Rondevlei	Final
1/5 yr	Original	3,22	2,72	2,37	2,37	2,34
	With sill	2,85 [0,37]	2,42 [0,30]	2,10 [0,27]	2,10 [0,27]	2,05 [0,29]
1/10 yr	Original	3,61	2,96	2,56	2,56	2,52
	With sill	3,07 [0,54]	2,56 [0,40]	2,16 [0,40]	2,16 [0,40]	2,07 [0,45]
1/20 yr	Original	3,88	3,11	2,68	2,68	2,65
	With sill	3,21 [0,67]	2,65 [0,46]	2,20 [0,48]	2,20 [0,48]	2,09 [0,56]
1/50 yr	Original	4,01	3,20	2,77	2,77	2,74
	With sill	3,28 [0,73]	2,72 [0,48]	2,25 [0,52]	2,25 [0,52]	2,10 [0,64]
1/100 yr	Original	4,93	3,63	3,16	3,16	3,12
	With sill	3,67 [1,26]	2,95 [0,78]	2,38 [0,78]	2,38 [0,78]	2,12 [1,00]

[] Reduction

8.4. Calculation of Flow and Scour at the Touws River Mouth

The scouring of the sill at the mouth was schematized by using the equation

$$S = \frac{0,05v^5}{g\frac{1}{2}\Delta_s^2D_{50}C^3} \quad (\text{Delft Hydraulics Laboratory, 1976})$$

where: g = gravitational acceleration
 Δ_s = specific gravity of sand
 D_{50} = grain size of sand
 v = velocity at sill
 C = friction (Chezy coefficient)
 S = scouring per time unit and unit width.

Erosion per time unit:

$$\Delta h = \frac{Kv^5\Delta t}{C^3L}$$

where: $K = \frac{0,05}{g\frac{1}{2}\Delta_s^2D_{50}} = 19,5$ for $D_{50} = 0,3 \text{ mm}$, $\Delta_s = 1.91$

Δt = time interval
 L = length of sill

$$\Delta h = \frac{19,5v^5\Delta t}{C^3L}$$

The sill was allowed to scour to 1,0 m to MSL at which it was assumed to be rigid. The dimensions of the sill were 120 m long and the width was assumed to be 40 m (although the entrance is 90 m wide it will not be necessary to open it over the entire width).

8.5. Results of Tests with a Movable Bed Sill

Tests with a movable bed, or scouring, sill at the estuary mouth were made for two conditions. In the first series of tests the connections between the lakes were assumed to be as existing (that is, the connections between the lakes were not dredged). For the second series of tests the connections between the lakes were dredged.

8.5.1. Results of theoretical floods with a scouring sill and the original layout (that is, undredged channels).

The results are shown in Figures 17.1a-e and the maximum water levels in the lakes for the original layout with and without a sill are indicated below.

With or without sill	Floods	Water levels (m)			
		Wilderness	Onder-Langvlei	Bo-Langvlei	Rondevlei
Without	1:5 yr	3,22	2,72	2,37	2,37
With	"	2,90	2,45	2,11	2,11
Without	1:10 yr	3,61	2,96	2,56	2,56
With	"	3,11	2,57	2,13	2,13
Without	1:20 yr	3,88	3,11	2,68	2,68
With	"	3,22	2,64	2,14	2,14
Without	1:50 yr	4,01	3,20	2,77	2,77
With	"	3,27	2,68	2,18	2,18
Without	1:100 yr	4,93	3,63	3,16	3,16
With	"	3,69	2,80	2,19	2,19

8.5.2. Results of theoretical flood with a scouring sill and the channels dredged

Figures 17.2a and 17.2b indicate the response of the system with the scouring sill and the channels being dredged for theoretical floods of 1 in 50 and 1 in 100 years.

Flood	Wilderness	Onder-Langvlei	Bo-Langvlei	Rondevlei
1:50 yr	3,30	2,52	2,35	2,35
1:100 yr	3,68	2,60	2,35	2,35

9. CONCLUSIONS

(1) Prototype data for use in model calibration were limited. However, one complete data set of a flood during January 1979 was available and was used for calibration of the model. This present calibration has been limited to a flood event with the estuary mouth closed.

The opening of the estuary mouth, either naturally or artificially, has in the past not been sufficiently monitored to provide sufficient information for model calibration. During the period of preparation of this report the artificial opening of the estuary mouth (2 December 1980) was monitored by NRIO and this information is at present being prepared for further verification of the model.

(2) The model was used to investigate the influence of dredging on the lake system and to determine flood lines resulting from the predicted flood events.

a. Dredging:

Dredging the Serpentine will not improve the system markedly, although the peak water level at Wilderness will be lowered by a few centimetres. This is because of the relatively small storage area of the lagoon and the length of the Serpentine.

The dredging of the connection between Onder-Langvlei and Bo-Langvlei will improve the flow in the system considerably (Section 6).

The water levels in Onder-Langvlei will be lowered during a flood and it will take only a quarter of the time as for the original layout for the lakes to come to the same level (80 hours instead of 400 hours).

It must be kept in mind that while the inflow to the lakes improves because of dredging, the outflow will also increase. This will be of major importance following a flood when the estuary mouth scours. The system will drain down and the levels in the lakes will be determined by the height of the interconnections between the lakes as illustrated in Figure 18.

Management of the water levels in the lake system would be facilitated by a control mechanism in the form of a sluice gate in the Serpentine.

The sluice gate would be open under normal conditions but would allow retention of water in the lakes during the periods when the estuary mouth had been scoured as a result of flood. When the mouth subsequently closes due to sand movement, this water could be used to raise the water level in the estuary. For example: if the lagoon is drained down to 0,5 m and the water levels in the upper lakes maintained at 1,5 m to MSL the level in the upper lakes will drop with ≈ 20 cm when the lagoon is filled up to the same level as the lakes (1,3 m to MSL).

b. Flood levels:

The maximum water levels for the Wilderness lagoon, Onder-Langvlei, Bo-Langvlei and Rondevlei for 1 in 5, 10, 20, 50 and 100 year floods are in Section 5 and the influence of dredging on these conditions in Section 6.

(3) Preliminary tests were done with schematized rigid and scouring sills at the Touws River mouth. The tests gave an indication of the response of the system but because of a lack of prototype data it is not possible at present to draw definite conclusions. However, when a sill is maintained at 2,0 m to MSL it will provide a safety for high-intensity floods. The equations for overflow and scouring are incorporated in the hydraulic model and can be tested as soon as prototype data from the monitoring of the estuary mouth opening during December 1980 has been analysed.

10. RECOMMENDATIONS

It is recommended that:

- (1) The Serrentine be left undisturbed.
- (2) The connection between Onder-Langvlei and Bo-Langvlei be dredged to a level of 0,0 m to MSL.
- (3) A sluice be installed in the Serrentine. This would not be operated under normal circumstances but would permit retention of water in the lakes, at a suggested water level of 1,5 m to MSL, during periods when the mouth is open.
- (4) The sand sill at the estuary mouth should be maintained at a level of +2,0 m to MSL.

REFERENCES

DELFT HYDRAULICS LABORATORY (1976). Coastal Sediment Transport. Computation of Longshore Transport. Report R968-I.

GÖRGENS, A.H.M. (1979). Estimated flood hydrographs for certain Wilderness streams. Rhodes University, Hydrological Research Unit. Special Report 1/79.

GÖRGENS, A.H.M. (1980). Runhydrographs for three Wilderness streams. Rhodes University. Hydrological Research Unit. Special Report 1/80.

TABLE I/1: WILDERNESS CROSS-SECTIONAL AREAS

TABLE I/2: WILDERNESS HYDRAULIC RADII

TABLE I/3: WILDERNESS STORAGE AREAS

TABLE I/1

WILDERNESS CROSS-SECTIONAL AREAS

SECTIONS

LEVEL (M)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
-1.0	5.00	2.00	33.00	1.00	1.00	1.00	1.00	373.00	1.00	1.00	175.00	1.00	1.00	1.00	1.00
-0.5	26.00	9.00	50.00	1.00	1.00	1.00	1.00	482.00	1.00	1.00	330.00	1.00	1.00	1.00	1.00
0.0	53.00	19.00	70.00	13.00	1.00	10.00	1.00	599.00	1.00	1.00	514.00	1.00	1.00	13.00	10.00
0.5	85.00	33.00	94.00	32.00	5.00	15.00	1.00	722.00	1.00	1.00	730.00	1.00	1.00	31.00	20.00
1.0	123.00	51.00	122.00	54.00	12.00	20.00	7.00	852.00	5.00	29.00	976.00	5.00	1.00	52.00	30.00
1.5	168.00	74.00	156.00	82.00	26.00	25.00	44.00	990.00	12.00	79.00	1246.00	25.00	1.00	74.00	40.00
2.0	220.00	104.00	198.00	114.00	48.00	30.00	100.00	1135.00	20.00	137.00	1538.00	58.00	1.00	97.00	50.00
2.5	278.00	140.00	246.00	150.00	74.00	35.00	178.00	1286.00	48.00	201.00	1848.00	106.00	0.00	121.00	60.00
3.0	344.00	182.00	304.00	202.00	108.00	40.00	266.00	1440.00	84.00	270.00	2172.00	168.00	1.00	146.00	70.00
3.5	414.00	228.00	370.00	258.00	144.00	45.00	364.00	1600.00	128.00	344.00	2510.00	240.00	1.00	172.00	80.00
4.0	492.00	280.00	442.00	318.00	184.00	50.00	470.00	1760.00	178.00	424.00	2856.00	322.00	1.00	198.00	90.00
4.5	574.00	334.00	514.00	382.00	226.00	55.00	580.00	1924.00	234.00	508.00	3208.00	412.00	1.00	225.00	100.00
5.0	654.00	392.00	600.00	452.00	274.00	60.00	692.00	2040.00	294.00	594.00	3568.00	508.00	0.00	252.00	110.00

TABLE I/2

WILDERNESS HYDRAULIC RADII

SECTIONS

LEVEL (M)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
-1.0	.15	.23	1.10	.01	.01	.01	.01	1.78	.01	.01	.63	.01	.01	.01	.01
-0.5	.56	.50	1.35	.01	.01	.01	.01	2.15	.01	.01	.96	.01	.01	.01	.01
0.0	.89	.76	1.59	.38	.01	.50	.01	2.50	.01	.01	1.29	.01	.01	.38	.50
.5	1.21	1.04	1.80	.81	.01	.75	.10	2.85	.01	.01	1.59	.01	.01	.80	1.00
1.0	1.50	1.29	1.97	1.14	.52	1.00	.50	3.17	.55	.50	1.88	.50	.01	1.20	1.50
1.5	1.77	1.42	2.06	1.36	.74	1.25	.50	3.51	.55	.73	2.21	.50	.01	1.63	2.00
2.0	2.00	1.57	2.20	1.55	.99	1.50	.72	3.85	.55	1.12	2.55	.73	.01	2.04	2.50
2.5	2.25	1.79	2.33	1.77	1.24	1.75	1.07	4.20	.73	1.50	2.90	.93	.01	2.47	3.00
3.0	2.53	2.02	2.46	1.99	1.53	2.00	1.41	4.59	1.02	1.90	3.27	1.26	.01	2.84	3.50
3.5	2.77	2.29	2.68	2.22	1.89	2.25	1.78	4.97	1.36	2.21	3.67	1.56	.01	3.30	4.00
4.0	3.08	2.45	2.95	2.52	2.18	2.50	2.15	5.40	1.55	2.59	4.08	1.87	.01	3.74	4.50
4.5	3.45	2.99	3.28	2.86	2.52	2.75	2.55	5.82	2.02	2.99	4.51	2.19	.01	4.16	5.00
5.0	3.83	3.34	3.70	3.23	2.85	3.00	2.95	6.33	2.95	3.34	4.93	2.54	.01	4.58	5.50

TABLE I/3

1	WILDERNESS STORAGE AREAS														
	SECTIONS														
LEVEL(M)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
-1.0	5000.	5000.	20000.	5000.	5000.	5000.	5000.	796000.	269000.	140000.	920000.	1100000.	1050000.	5000.	80000.
-0.5	40000.	15000.	25000.	6500.	10000.	5000.	5000.	835000.	290000.	140000.	920000.	1100000.	1050000.	10000.	80000.
0.0	80000.	25000.	30000.	8000.	15000.	70000.	10000.	875000.	305000.	140000.	920000.	1100000.	1050000.	18000.	80000.
0.5	120000.	35000.	35000.	9000.	35000.	70000.	25000.	945000.	344000.	140000.	920000.	1100000.	1050000.	50000.	80000.
1.0	176000.	75000.	45000.	10000.	70000.	70000.	100000.	1200000.	430000.	140000.	920000.	1100000.	1050000.	70000.	80000.
1.5	218000.	120000.	90000.	20000.	110000.	300000.	450000.	1450000.	520000.	300000.	1100000.	1480000.	1350000.	110000.	80000.
2.0	247000.	155000.	190000.	60000.	140000.	360000.	570000.	1600000.	640000.	330000.	1210000.	1590000.	1550000.	140000.	80000.
2.5	271000.	160000.	240000.	100000.	180000.	421000.	792000.	1700000.	890000.	379000.	1310000.	1660000.	2040000.	180000.	80000.
3.0	304000.	160000.	280000.	161000.	210000.	613000.	870000.	1750000.	920000.	406000.	1330000.	1850000.	2240000.	210000.	80000.
3.5	304000.	160000.	280000.	161000.	210000.	613000.	870000.	1750000.	920000.	406000.	1330000.	1850000.	2240000.	210000.	80000.
4.0	304000.	160000.	280000.	161000.	210000.	613000.	870000.	1750000.	920000.	406000.	1330000.	1850000.	2240000.	210000.	80000.
4.5	304000.	160000.	280000.	161000.	210000.	613000.	870000.	1750000.	920000.	406000.	1330000.	1850000.	2240000.	210000.	80000.
5.0	304000.	160000.	280000.	161000.	210000.	613000.	870000.	1750000.	920000.	406000.	1330000.	1850000.	2240000.	210000.	80000.

TABLE II: WILDERNESS LAKES STORAGE VOLUMES

	Volumes ($\text{m}^3 \times 10^3$)									
	Water level (m)									
	-1	-0,5	0	0,5	1,0	1,5	2,0	2,5		
Wilderness	198,5	397,0	595,5	794,0	992,5	1 520,0	2 230,0	3 242,0		
Onder-Langvlei	757,0	1 514,0	2 271,0	3 028,0	3 785,0	4 808,5	5 882,0	7 088,0		
Bo-Langvlei	1 023,5	2 047,0	3 070,5	4 094,0	5 117,5	6,487,5	8 018,5	9 789,0		
Rondevlei	610,5	1 221,0	1 831,5	2 442,0	3 052,5	3 763,5	4 538,0	5 418,0		
Total	2 589,5	5 179,0	7 768,5	10 358,0	12 947,5	16 579,5	20 668,5	25 537,0		

TABLE III/1: PROTOTYPE DATA 25.10.1978 - 6.2.1979

Date	Time	Water levels (m)				Touws flow (m ³ /s)
		Wilder- ness	Onder Langvlei	Bo Langvlei	Ronde	
25.10.78	00h00	1,64	1,66	1,60	1,62	0,55
	12h00	1,64	1,66	1,60	1,62	0,33
	18h00	1,65	1,66	1,60	1,61	0,30
26.10.78	00h00	1,65	1,66	1,60	1,61	0,27
	06h00	1,64	1,66	1,60	1,62	0,24
	18h00	1,64	1,66	1,60	1,62	0,21
27.10.78	00h00	1,63	1,66	1,60	1,62	0,19
	00h00	1,63	1,66	1,60	1,62	0,19
	18h00	1,63	1,66	1,60	1,62	0,14
28.10.78	12h00	1,63	1,66	1,60	1,62	0,14
	18h00	1,62	1,66	1,60	1,62	0,11
29.10.78	12h00	1,61	1,66	1,60	1,62	0,11
30.10.78	00h00	1,61	1,65	1,60	1,62	0,11
	18h00	1,61	1,65	1,60	1,62	0,09
31.10.78	00h00	1,61	1,64	1,60	1,62	0,09
	18h00	1,60	1,64	1,60	1,62	0,09
1.11.78	12h00	1,60	1,64	1,60	1,62	0,09
	18h00	1,61	1,64	1,61	1,62	0,09
2.11.78	00h00	1,67	1,69	1,67	1,70	0,16
	04h00	1,77	1,76	1,73	1,72	22,18
	06h00	1,88	1,80	1,78	1,75	22,18
	08h00	2,03	1,84	1,82	1,77	17,60
	10h00	2,11	1,90	1,85	1,79	15,01
	12h00	2,16	1,95	1,86	1,81	15,01
	14h00	2,19	1,99	1,86	1,82	11,81
	16h00	2,22	2,03	1,86	1,83	8,90
	18h00	2,23	2,05	1,86	1,84	6,91
	21h00	2,21	2,09	1,86	1,85	5,68
	00h00	2,14	2,11	1,87	1,86	4,54
	02h00	2,02	2,12	1,87	1,87	4,03
	04h00	1,81	2,11	1,87	1,87	3,54
3.11.78	06h00	1,65	2,10	1,88	1,88	3,30
	08h00	1,53	2,08	1,88	1,89	2,84
	10h00	1,41	2,05	1,88	1,89	2,62
	12h00	1,23	2,03	1,89	1,89	2,40
	00h00	1,28	1,90	1,89	1,90	1,42
	06h00	1,29	1,86	1,89	1,90	1,25
	12h00	1,31	1,82	1,89	1,90	1,09
	18h00	1,28	1,78	1,89	1,90	0,94
5.11.78	00h00	1,29	1,75	1,89	1,90	0,80
	06h00	1,30	1,72	1,88	1,89	0,67
	12h00	1,30	1,70	1,88	1,89	0,67
	18h00	1,32	1,67	1,87	1,89	0,55
6.11.78	00h00	1,31	1,64	1,87	1,88	0,55
	06h00	1,31	1,62	1,86	1,87	0,44
	18h00	1,36	1,58	1,86	1,86	0,37

TABLE III/1: (continued)

Date	Time	Water levels (m)				Touws flow (m ³ /s)
		Wilder- ness	Onder Langvlei	Bo Langvlei	Ronde	
7.11.78	00h00	1,35	1,56	1,85	1,86	0,33
	06h00	1,32	1,54	2,84	1,85	0,33
	12h00		1,52	1,84	1,85	0,30
	18h00		1,51	1,84	1,85	0,30
8.11.78	00h00		1,48	1,83	1,83	0,30
	06h00		1,47	1,82	1,83	0,27
	12h00		1,45	1,82	1,82	0,27
9.11.78	00h00		1,45	1,81	1,81	0,27
	06h00		1,42	1,80	1,80	0,24
	12h00		1,40	1,80	1,80	0,24
	18h00		1,39	1,80	1,79	0,24
10.11.78	00h00		1,38	1,79	1,79	0,24
	06h00		1,37	1,78	1,78	0,21
	12h00		1,36	1,78	1,78	0,19
	18h00		1,35	1,77	1,77	0,19
11.11.78	06h00		1,34	1,76	1,77	0,19
	12h00		1,34	1,76	1,76	0,16
12.11.78	00h00		1,34	1,75	1,76	0,16
	12h00		1,33	1,74	1,75	0,16
13.11.78	06h00		1,33	1,73	1,73	0,16
	18h00		1,33	1,72	1,72	0,14
14.11.78	06h00		1,33	1,71	1,72	0,14
	12h00		1,32	1,70	1,71	0,14
	18h00		1,29	1,70	1,70	0,11
15.11.78	00h00	1,25	1,29	1,70	1,69	0,11
	06h00	1,36	1,29	1,70	1,69	0,11
	12h00	1,21	1,29	1,70	1,68	0,11
	18h00	1,37	1,29	1,70	1,68	0,11
16.11.78	00h00	1,25	1,29	1,69	1,67	0,09
	06h00	1,29	1,29	1,69	1,67	0,09
	12h00	1,22	1,29	1,69	1,67	0,09
	18h00	1,28	1,29	1,68	1,66	0,09
17.11.78	00h00	1,21	1,29	1,68	1,66	0,09
	06h00	1,22	1,29	1,68	1,66	0,09
	12h00	1,18	1,28	1,67	1,65	0,09
	18h00	1,21	1,28	1,67	1,65	0,09
18.11.78	00h00	1,18	1,28	1,67	1,65	0,09
	06h00	1,21	1,28	1,66	1,64	0,09
	12h00	1,24	1,28	1,66	1,63	0,09
19.11.78	06h00	1,20	1,28	1,65	1,63	0,09
	12h00	1,18	1,28	1,65	1,63	0,09
20.11.78	00h00	1,15	1,28	1,64	1,62	0,09
	12h00	1,15	1,28	1,63	1,62	0,07
21.11.78	00h00		1,27	1,63	1,61	0,07
	12h00		1,26	1,62	1,61	0,07
22.11.78	00h00		1,26	1,60	1,61	0,07
23.11.78	00h00		1,26	1,59	1,61	0,07
	18h00		1,26	1,58	1,61	0,07
24.11.78	00h00		1,26	1,58	1,60	0,07
	06h00		1,26	1,58	1,59	0,07

TABLE III/1: (continued)

Date	Time	Water levels (m)				Touws flow (m ³ /s)
		Wilder- ness	Onder Langvlei	Bo Langvlei	Ronde	
25.11.78	00h00		1,25	1,58	1,59	0,05
	06h00		1,25	1,57	1,59	0,05
	12h00		1,25	1,57	1,58	0,05
26.11.78	00h00		1,25	1,57	1,57	0,05
	06h00		1,25	1,56	1,57	0,05
	18h00		1,25	1,56	1,55	0,05
27.11.78	00h00		1,25	1,55	1,55	0,05
	18h00		1,25	1,54	1,55	0,05
28.11.78	18h00		1,25	1,53	1,55	0,05
29.11.78	00h00		1,24	1,52	1,55	0,05
	12h00		1,24	1,52	1,54	0,05
30.11.78	00h00		1,24	1,52	1,53	0,05
1.12.78	00h00	1,31	1,24	1,51	1,53	0,05
	12h00	1,30	1,24	1,51	1,52	0,05
	18h00	1,29	1,24	1,50	1,51	0,05
2.12.78	06h00	1,27	1,24	1,50	1,51	0,05
	18h00	1,24	1,24	1,50	1,51	0,05
3.12.78	06h00	1,24	1,24	1,49	1,51	0,05
	18h00	1,23	1,24	1,49	1,50	0,05
4.12.78	06h00	1,23	1,24	1,48	1,50	0,05
	12h00	1,23	1,24	1,48	1,49	0,05
5.12.78	12h00	1,23	1,24	1,47	1,49	0,05
	18h00	1,20	1,24	1,47	1,48	0,05
6.12.78	18h00	1,20	1,24	1,46	1,48	0,05
7.12.78	06h00	1,20	1,24	1,46	1,47	0,05
8.12.78	06h00	1,20	1,24	1,45	1,46	0,04
	12h00	1,20	1,24	1,45	1,45	0,04
9.12.78	00h00	1,20	1,24	1,44	1,45	0,04
	12h00	1,20	1,24	1,44	1,44	0,05
	18h00	1,20	1,24	1,44	1,46	0,05
10.12.78	06h00	1,20	1,24	1,44	1,46	0,07
	12h00	1,20	1,24	1,44	1,46	0,09
	18h00	1,21	1,24	1,45	1,46	0,55
11.12.78	00h00	1,21	1,24	1,45	1,46	1,25
	06h00	1,21	1,24	1,45	1,46	0,94
	12h00	1,25	1,24	1,45	1,46	0,67
	18h00	1,27	1,24	1,45	1,46	0,67
12.12.78	06h00	1,27	1,24	1,44	1,46	0,55
	12h00	1,28	1,25	1,44	1,45	0,33
	18h00	1,33	1,30	1,44	1,45	0,30
13.12.78	12h00	1,33	1,31	1,44	1,45	0,21
	18h00	1,33	1,32	1,44	1,45	0,19
14.12.78	18h00	1,32	1,32	1,43	1,44	0,14
15.12.78	12h00	1,32	1,32	1,43	1,44	0,11
	18h00	1,32	1,34	1,43	1,44	0,11
16.12.78	12h00	1,32	1,34	1,43	1,47	0,14
	18h00	1,43	1,34	1,41	1,45	0,11
17.12.78	00h00	1,47	1,35	1,41	1,44	0,11
	06h00	1,47	1,35	1,41	1,43	0,11
	12h00	1,46	1,36	1,41	1,43	0,11
	18h00	1,43	1,37	1,41	1,43	0,11

TABLE III/1: (continued)

Date	Time	Water levels (m)				Touws flow (m ³ /s)
		Wilder ness	Onder Langvlei	Bo Langvlei	Ronde	
18.12.78	00h00	1,42	1,37	1,41	1,43	0,11
	06h00	1,42	1,37	1,41	1,42	0,09
	12h00	1,40	1,37	1,41	1,42	0,09
	18h00	1,40	1,37	1,41	1,41	0,09
19.12.78	12h00	1,39	1,38	1,41	1,41	0,07
	18h00	1,35	1,38	1,40	1,41	0,07
20.12.78	00h00	1,35	1,39	1,40	1,41	0,07
	18h00	1,34	1,39	1,39	1,41	0,07
21.12.78	12h00	1,34	1,39	1,39	1,40	0,07
22.12.78	00h00	1,34	1,38	1,39	1,40	0,07
	12h00	1,34	1,38	1,38	1,41	0,07
23.12.78	00h00	1,34	1,38	1,38	1,40	0,16
	06h00	1,34	1,38	1,38	1,40	3,30
	12h00	1,36	1,38	1,38	1,39	1,99
	18h00	1,41	1,38	1,38	1,39	1,42
24.12.78	00h00	1,42	1,38	1,38	1,39	1,09
	12h00	1,45	1,38	1,38	1,39	0,67
	18h00	1,46	1,40	1,38	1,38	0,55
25.12.78	12h00	1,46	1,41	1,38	1,38	0,24
	18h00	1,45	1,42	1,38	1,38	0,21
26.12.78	00h00	1,45	1,42	1,37	1,38	0,19
	12h00	1,43	1,42	1,37	1,38	0,16
	18h00	1,41	1,44	1,37	1,38	0,14
28.12.78	12h00	1,41	1,44	1,37	1,38	0,16
	18h00	1,39	1,44	1,37	1,38	0,16
	18h00	1,39	1,44	1,36	1,38	0,14
30.12.78	06h00	1,39	1,44	1,36	1,37	0,11
31.12.78	00h00	1,39	1,44	1,36	1,37	0,09
	06h00	1,39	1,43	1,36	1,37	0,14
	12h00	1,39	1,46	1,40	1,42	45,37
2.1.79	14h00	1,49	1,46	1,41	1,42	33,53
	15h00	1,65	1,46	1,41	1,42	31,35
	16h00	1,78	1,46	1,41	1,42	24,12
	17h00	1,87	1,46	1,42	1,42	20,30
	18h00	1,93	1,49	1,42	1,43	17,58
	00h00	2,04	1,57	1,42	1,43	11,05
	08h00	2,08	1,68	1,42	1,43	7,55
3.1.79	12h00	2,09	1,73	1,43	1,43	5,10
	18h00	2,09	1,80	1,44	1,43	3,30
4.1.79	00h00	2,04	1,84	1,44	1,43	2,40
	06h00	1,99	1,88	1,44	1,44	1,79
	12h00	1,96	1,89	1,44	1,45	1,42
	18h00	1,95	1,90	1,46	1,45	1,25
5.1.79	00h00	1,93	1,90	1,46	1,46	0,94
	06h00	1,93	1,90	1,47	1,47	0,80
	12h00	1,90	1,90	1,47	1,49	0,80
	18h00	1,90	1,90	1,48	1,49	0,67
6.1.79	00h00	1,89	1,90	1,49	1,50	0,55
	06h00	1,89	1,89	1,49	1,51	0,55
	12h00	1,87	1,89	1,50	1,51	0,44
	18h00	1,87	1,88	1,51	1,52	0,37

TABLE III/1: (continued)

Date	Time	Water levels (m)				Touws flow (m ³ /s)
		Wilder ness	Onder Langvlei	Bo Langvlei	Ronde	
7.1.79	00h00	1,86	1,87	1,52	1,52	0,37
	06h00	1,86	1,86	1,52	1,53	0,33
	12h00	1,85	1,85	1,53	1,53	0,30
	18h00	1,84	1,84	1,54	1,53	0,30
8.1.79	00h00	1,83	1,84	1,54	1,54	0,27
	06h00	1,83	1,83	1,54	1,53	0,24
	12h00	1,80	1,82	1,54	1,56	0,24
	18h00	1,79	1,82	1,54	1,56	0,24
9.1.79	00h00	1,79	1,81	1,55	1,57	0,24
	06h00	1,79	1,80	1,55	1,57	0,21
	12h00	1,77	1,80	1,56	1,58	0,21
	18h00	1,76	1,78	1,57	1,59	0,19
10.1.79	00h00	1,75	1,78	1,57	1,59	0,19
	18h00	1,75	1,77	1,58	1,60	0,19
11.1.79	06h00	1,75	1,76	1,58	1,60	0,16
	12h00	1,73	1,75	1,59	1,61	0,16
	18h00	1,73	1,74	1,59	1,61	0,16
12.1.79	06h00	1,72	1,74	1,60	1,62	0,16
	12h00	1,71	1,74	1,60	1,62	0,14
	18h00	1,70	1,73	1,60	1,62	0,14
13.1.79	00h00	1,70	1,72	1,60	1,62	0,14
	12h00	1,70	1,71	1,60	1,62	0,14
	18h00	1,68	1,71	1,60	1,62	0,14
14.1.79	00h00	1,68	1,70	1,61	1,62	0,14
	18h00	1,67	1,69	1,61	1,62	0,11
15.1.79	06h00	1,67	1,68	1,61	1,63	0,11
	12h00	1,66	1,68	1,61	1,63	0,11
16.1.79	00h00	1,66	1,68	1,62	1,63	
	12h00	1,65	1,68	1,62	1,63	
	18h00	1,63	1,66	1,62	1,63	
17.1.79	18h00	1,63	1,65	1,62	1,63	
18.1.79	12h00	1,61	1,65	1,62	1,63	
19.1.79	00h00	1,61	1,64	1,62	1,63	
	18h00	1,60	1,64	1,62	1,63	
20.1.79	12h00	1,57	1,64	1,62	1,64	
	18h00	1,57	1,63	1,61	1,64	
21.1.79	00h00	1,57	1,62	1,61	1,63	
	18h00	1,57	1,62	1,61	1,62	
22.1.79	00h00	1,57	1,61	1,61	1,62	
23.1.79	00h00	1,57	1,60	1,60	1,62	
26.1.79	00h00	1,57	1,60	1,59	1,62	
	12h00	1,57	1,59	1,59	1,61	
18.1.79	06h00	1,57	1,58	1,59	1,61	
	18h00	1,55	1,58	1,59	1,61	
29.1.79	18h00	1,55	1,58	1,58	1,60	
30.1.79	12h00	1,55	1,58	1,58	1,59	
	18h00	1,55	1,57	1,58	1,57	
1.2.79	06h00	1,55	1,57	1,57	1,57	
2.2.79	18h00	1,55	1,56	1,57	1,57	
3.2.79	00h00	1,54	1,56	1,57	1,57	
	06h00	1,54	1,56	1,56	1,57	
	18h00	1,53	1,56	1,56	1,57	
4.2.79	18h00	1,51	1,56	1,56	1,57	
5.2.79	12h00	1,51	1,56	1,55	1,57	
6.2.79	12h00	1,51	1,55	1,55	1,56	

TABLE III/2: PROTOTYPE DATA 17.7.1979 - 20.8.1979

Date	Time	Water levels (m)				Touws flow (m ³ /s)
		Wilder ness	Onder Langvlei	Bo Langvlei	Ronde	
17.7.79	18h00	1,50	1,56	1,55	1,56	0,07
19.7.79	12h00	1,51	1,56	1,55	1,56	0,05
	18h00	1,51	1,56	1,56	1,56	0,05
20.7.79	12h00	1,52	1,56	1,56	1,57	0,09
21.7.79	00h00	1,52	1,56	1,56	1,57	0,14
	06h00	1,55	1,60	1,58	1,57	0,33
	12h00	1,59	1,62	1,60	1,59	1,42
	18h00	1,62	1,66	1,61	1,61	4,28
	21h00	1,67	1,68	1,61	1,61	6,28
22.7.79	00h00	1,73	1,70	1,61	1,62	5,68
	06h00	1,83	1,72	1,62	1,62	4,03
	12h00	1,85	1,75	1,63	1,63	2,40
	18h00	1,85	1,78	1,64	1,63	1,79
23.7.79	00h00	1,83	1,80	1,65	1,64	1,25
	06h00	1,80	1,81	1,66	1,65	0,94
	18h00	1,77	1,82	1,67	1,68	0,80
24.7.79	00h00	1,79	1,82	1,68	1,71	3,30
	06h00	1,83	1,85	1,70	1,71	5,39
	09h00	1,87	1,86	1,71	1,72	5,68
	12h00	1,91	1,88	1,72	1,72	4,82
	18h00	1,95	1,91	1,72	1,72	3,30
25.7.79	00h00	1,97	1,94	1,72	1,74	2,19
	06h00	1,97	1,95	1,72	1,77	1,42
	12h00	1,96	1,96	1,72	1,77	1,42
	18h00	1,95	1,96	1,72	1,78	1,09
26.7.79	00h00	1,94	1,96	1,77	1,79	1,09
	06h00	1,93	1,96	1,77	1,80	0,80
	12h00	1,92	1,96	1,77	1,81	0,80
	18h00	1,91	1,95	1,80	1,82	0,67
27.7.79	00h00	1,91	1,95	1,80	1,83	0,55
	12h00	1,89	1,94	1,80	1,84	0,55
	18h00	1,89	1,94	1,80	1,85	0,44
28.7.79	00h00	1,88	1,94	1,83	1,85	0,44
	06h00	1,88	1,93	1,83	1,86	0,37
	12h00	1,87	1,93	1,83	1,86	0,37
	18h00	1,87	1,92	1,83	1,87	0,33
29.7.79	06h00	1,86	1,92	1,86	1,87	0,30
	18h00	1,85	1,91	1,86	1,88	0,27
30.7.79	00h00	1,85	1,91	1,87	1,88	0,24
	06h00	1,85	1,91	1,87	1,89	0,24
	18h00	1,85	1,91	1,87	1,89	0,21
31.7.79	00h00	1,85	1,91	1,88	1,89	0,21
1.8.79	00h00	1,85	1,91	1,89	1,89	0,19
	18h00	1,85	1,91	1,89	1,91	0,19
2.8.79	18h00	1,85	1,91	1,90	1,91	0,16
3.8.79	12h00	1,85	1,92	1,90	1,91	0,16
4.8.79	18h00	1,85	1,91	1,90	1,91	0,14
5.8.79	06h00	1,85	1,91	1,91	1,91	0,11
	18h00	1,85	1,91	1,91	1,92	0,11

TABLE III/2: (continued)

Date	Time	Water levels (m)				Touws flow (m ³ /s)
		Wilder ness	Onder Langvlei	Bo Langvlei	Ronde	
7.8.79	12h00	1,84	1,91	1,91	1,92	0,09
8.8.79	12h00	1,83	1,91	1,91	1,93	0,09
	18h00	1,83	1,90	1,91	1,93	0,09
9.8.79	06h00	1,84	1,90	1,91	1,92	0,09
10.8.79	12h00	1,85	1,90	1,91	1,91	0,09
11.8.79	06h00	1,84	1,90	1,91	1,91	0,09
13.8.79	12h00	1,84	1,90	1,90	1,91	0,09
	18h00	1,83	1,90	1,90	1,91	0,09
14.8.79	00h00	1,83	1,90	1,90	1,90	0,09
	12h00	1,83	1,90	1,90	1,89	0,09
	18h00	1,83	1,89	1,89	1,89	0,09
15.8.79	00h00	1,83	1,89	1,89	1,88	0,09
16.8.79	12h00	1,83	1,89	1,88	1,88	0,09
18.8.79	18h00	1,85	1,89	1,88	1,88	0,09
19.8.79	00h00	1,83	1,89	1,88	1,87	0,09
20.8.79	12h00	1,83	1,89	1,88	1,87	0,09

TABLE IV: OPENING AND CLOSURE OF TOUW RIVER MOUTH

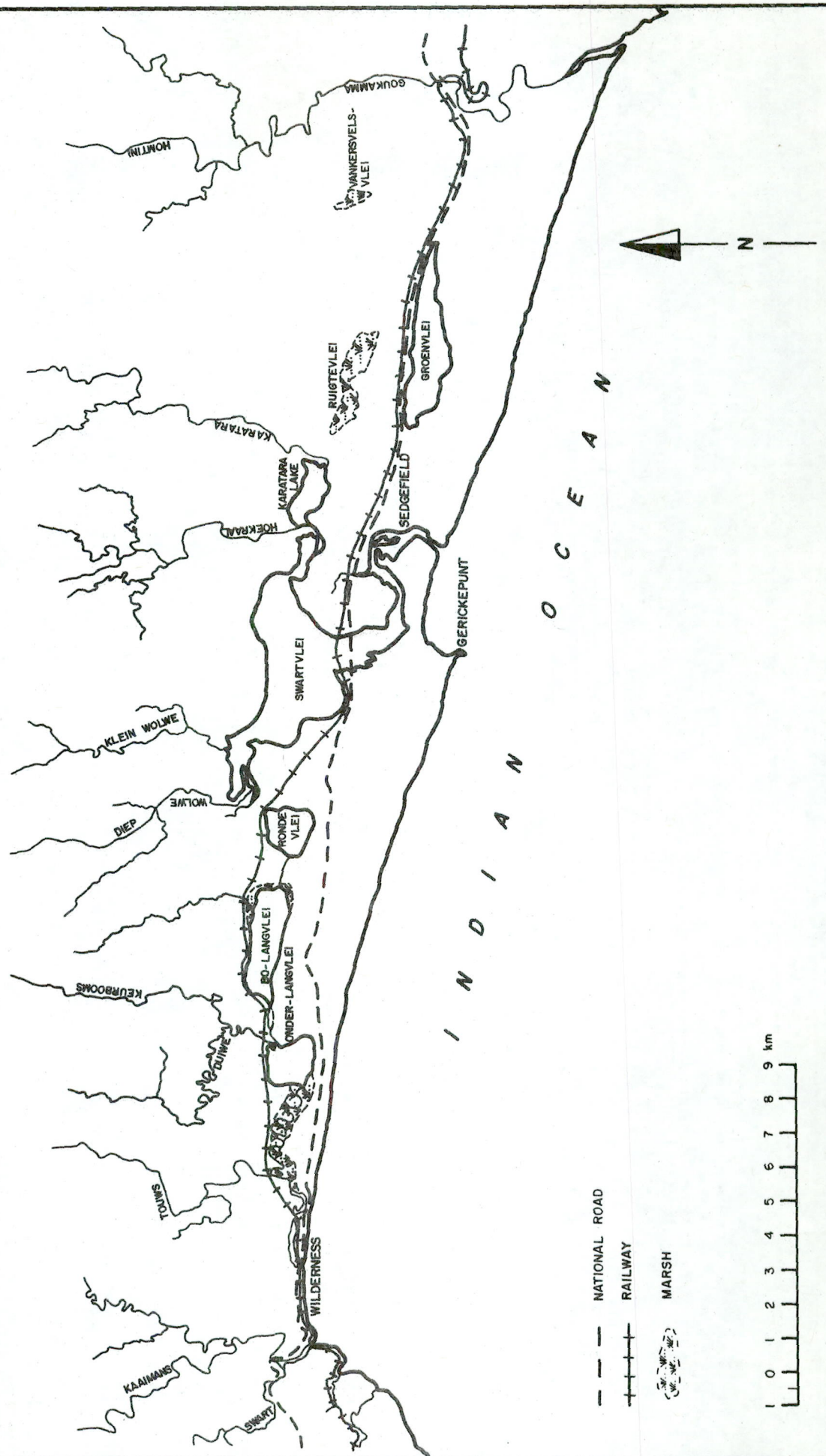
<u>Opening</u>	<u>Closure</u>	
15 September 1964	12 December 1964	
12 October 1965	3 December 1965	
1 February 1966	16 May 1966	
2 September 1966	22 October 1966	
17 February 1967	24 June 1967	
31 August 1967	24 November 1967	
30 November 1967	21 December 1967	
3 March 1968	1 July 1968	
5 September 1968	17 September 1968	
15 November 1968	29 November 1968	
17 June 1969	4 July 1969	
8 October 1970	6 November 1970	
7 December 1970	15 December 1970	
5 April 1971	7 May 1971	
18 June 1971	2 July 1971	
4 July 1971	26 July 1971	
30 July 1971	17 August 1971	
21 August 1971	27 November 1971	
27 November 1971	10 December 1971	
2 May 1972	7 June 1972	
1 April 1974	17 April 1974	
9 September 1974	Mouth skimmed	
13 September 1974	14 September 1974	
12 September 1975	?	
8 May 1977	23 May 1977	Closed naturally
26 May 1977	9 June 1977	Opened and closed naturally
2 November 1977	Mouth skimmed	
19 July 1978	Mouth skimmed	
2 November 1978	26 November 1978	Closed naturally
1 September 1979	1 October 1979	Opened mechanically Closed naturally

TABLE V/1: VOLUME INCREASE AND TOTAL DISCHARGE OF TOUW RIVER (JANUARY 1979)

Time (hours)	Total discharge of Touw $\times 10^3 \text{ m}^3$	Total volume of lakes $\times 10^3 \text{ m}^3$	Wilderness	Onder-Langvlei	Bo-Langvlei	Rondevlei
0	0		0	0	0	
6	2		0	0	0	
12	4	10	0	0	0	10 000
18	230	240	0	80 000	110 000	50 000
24	620	1 110	770 000	120 000	160 000	60 000
30	920	1 480	960 000	300 000	160 000	60 000
36	1 170	1 720	1 020 000	480 000	160 000	60 000
42	1 340	1 920	1 040 000	620 000	200 000	60 000
48	1 430	2 120	1 040 000	780 000	240 000	60 000
54	1 490	2 140	960 000	880 000	240 000	60 000
60	1 540	2 110	850 000	930 000	240 000	90 000
66	1 570	2 130	820 000	960 000	240 000	110 000
72	1 600	2 180	790 000	1 000 000	280 000	110 000
78	1 630	2 160	760 000	1 000 000	280 000	120 000
84	1 650	2 210	760 000	1 000 000	310 000	140 000
90	1 660	2 170	690 000	1 000 000	310 000	170 000
96	1 680	2 200	690 000	1 000 000	340 000	170 000
102	1 690	2 220	670 000	1 000 000	370 000	180 000
108	1 700	2 190	670 000	960 000	370 000	190 000
114	1 710	2 200	650 000	960 000	400 000	190 000
120	1 720	2 230	650 000	950 000	430 000	200 000
126	1 730	2 220	640 000	920 000	460 000	200 000
132	1 740	2 210	640 000	900 000	460 000	210 000
138	1 750	2 200	620 000	880 000	490 000	210 000
144	1 750	2 200	610 000	860 000	520 000	210 000
150	1 760	2 200	590 000	860 000	520 000	230 000
156	1 760	2 200	590 000	840 000	520 000	250 000
162	1 770	2 170	550 000	840 000	520 000	260 000
168	1 770	2 130	530 000	820 000	520 000	260 000
174	1 780	2 160	530 000	800 000	550 000	280 000
180	1 780	2 140	530 000	780 000	550 000	280 000
186	1 790	2 160	500 000	780 000	590 000	290 000
192	1 790	2 140	480 000	730 000	620 000	310 000
198	1 800	2 130	470 000	730 000	620 000	310 000
204	1 800	2 130	470 000	730 000	620 000	310 000
210	1 810	2 160	470 000	730 000	650 000	310 000
216	1 810	2 160	470 000	710 000	650 000	330 000
222	1 810	2 140	470 000	690 000	650 000	330 000
228	1 820	2 140	470 000	690 000	650 000	330 000
234	1 820	2 140	450 000	670 000	680 000	340 000
240	1 820	2 120	450 000	650 000	680 000	340 000
246	1 830	2 140	450 000	650 000	680 000	360 000
252	1 830	2 150	430 000	650 000	710 000	360 000
258	1 830	2 140	420 000	650 000	710 000	360 000

TABLE V/2: VOLUME INCREASE AND TOTAL DISCHARGE OF TOUW RIVER (JULY 1979)

Time (hours)	Total discharge of Touw $\times 10^3 \text{ m}^3$	Total volume of lakes $\times 10^3 \text{ m}^3$	Wilderness	Onder Langvlei	Bo-Langvlei	Rondevlei
0	10	0	0	0	0	0
6	10	0	0	0	0	0
12	11	20	20	0	0	0
18	12	50	20	0	30	0
24	14	50	20	0	30	0
30	15	50	20	0	30	0
36	17	90	40	0	30	20
42	19	90	40	0	30	20
48	21	90	40	0	30	20
54	26	270	80	80	90	20
60	45	450	130	110	160	50
66	110	630	170	190	190	80
72	230	900	320	290	190	100
78	270	1 120	470	330	220	100
84	340	1 250	500	390	250	110
90	390	1 340	500	450	280	110
96	420	1 420	470	500	320	130
102	440	1 440	420	520	350	150
108	460	1 410	390	520	350	150
114	480	1 490	370	540	380	200
120	510	1 590	400	540	410	240
126	610	1 790	470	610	470	240
132	730	2 030	600	670	500	260
138	810	2 150	660	730	500	260
144	870	2 290	700	800	500	290
150	910	2 360	700	820	500	340
156	940	2 360	680	840	500	340
162	970	2 350	660	840	500	350
168	990	2 540	650	840	680	370
174	1 010	2 530	620	840	680	390
180	1 030	2 530	610	840	680	400
186	1 050	2 520	600	820	680	420
192	1 060	2 630	600	820	770	440
198	1 070	2 610	580	820	770	440
204	1 080	2 580	560	800	770	450
210	1 090	2 590	560	800	770	460
216	1 100	2 670	540	800	870	460
222	1 110	2 670	540	780	870	480
228	1 120	2 660	530	780	870	480
234	1 130	2 650	530	750	870	500
240	1 130	2 730	530	750	950	500
246	1 140	2 710	510	750	950	500
252	1 150	2 720	510	750	950	510
258	1 150	2 690	500	730	950	510



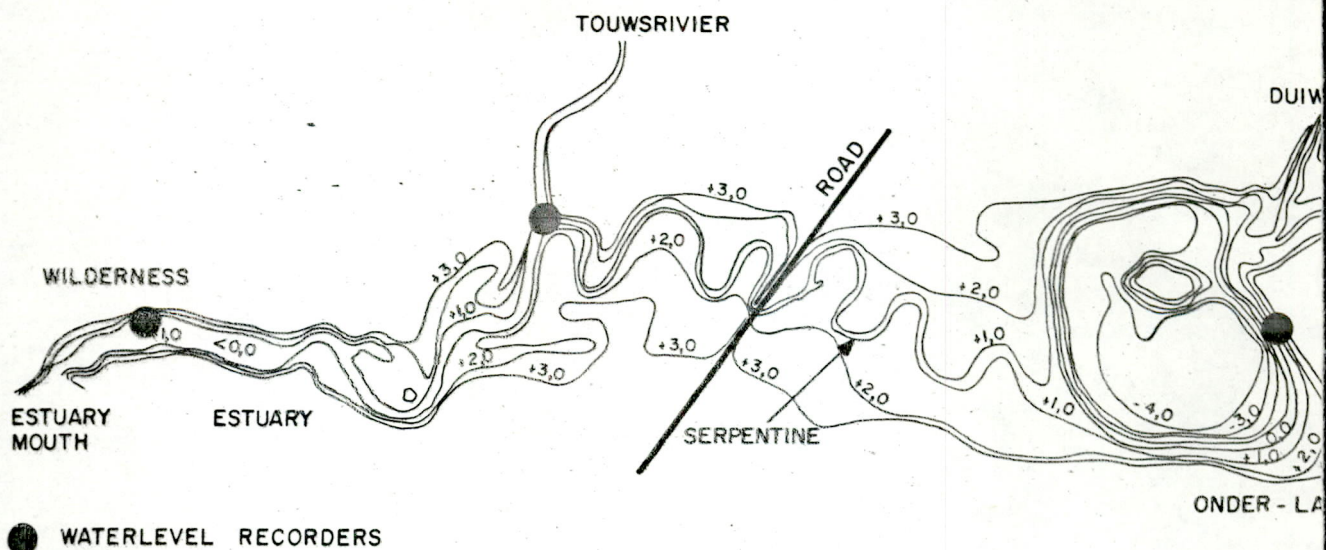
TRACED JGAN
 CHECKED
 DATE JULY 1981
 REF C/SEA 8113

WILDERNESS NUMERICAL STUDY

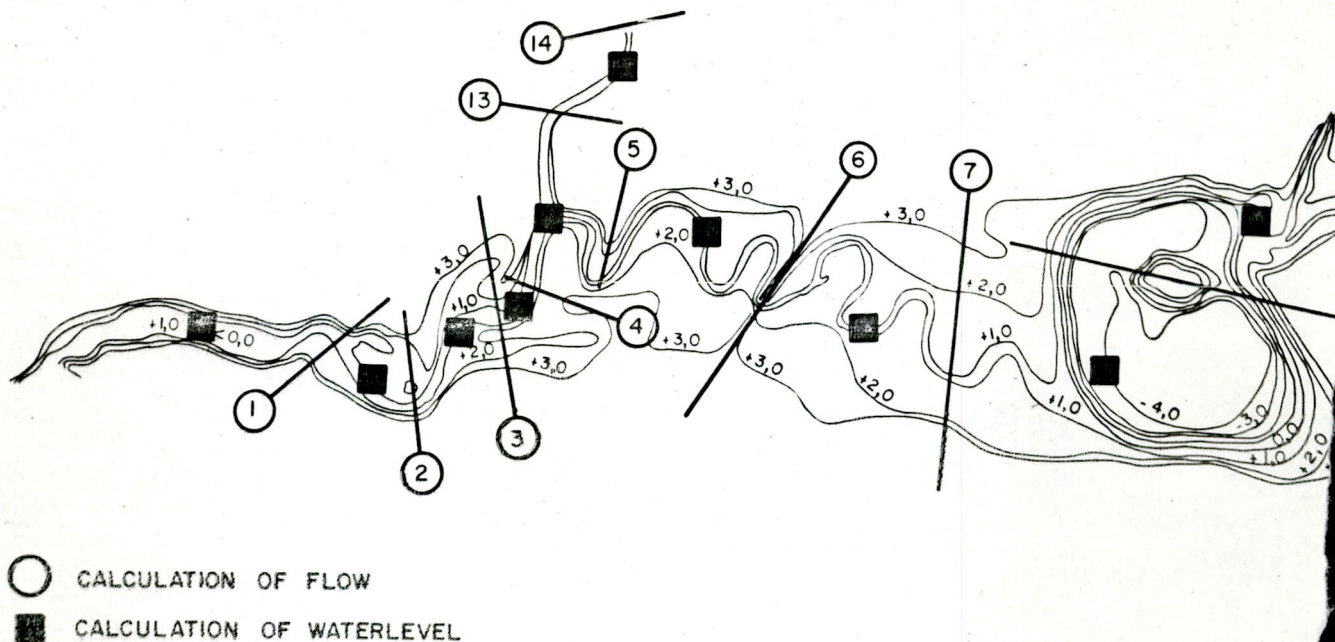
LOCALITY MAP OF THE WILDERNESS LAKES

FIGURE

10



1) CONTOURS OF THE WILDERNESS LAKES (LEVELS TO MSL)



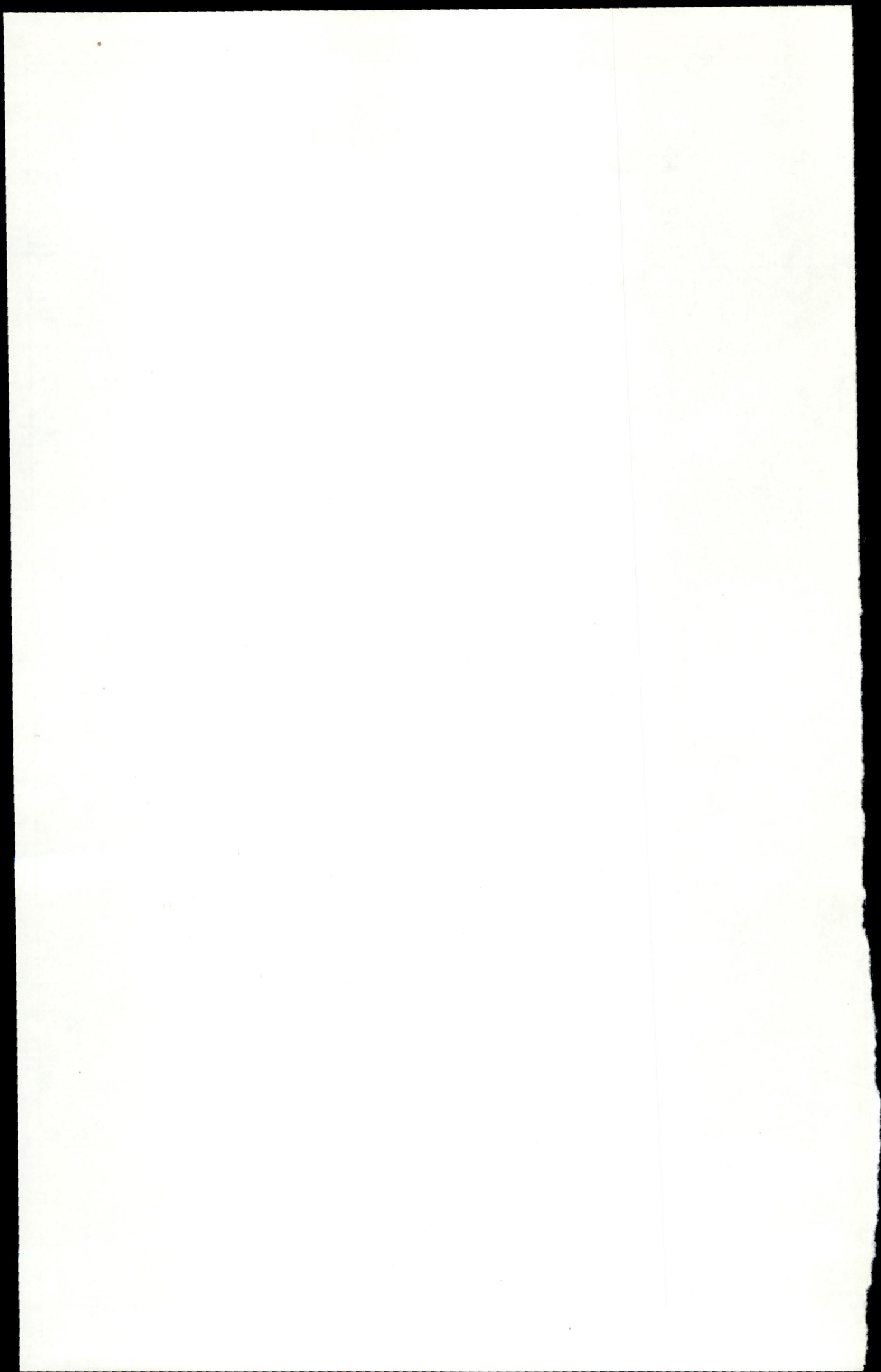
2) POSITIONS OF CROSS-SECTIONS, WHERE FLOW AND WATERLEVELS ARE CALCULATED

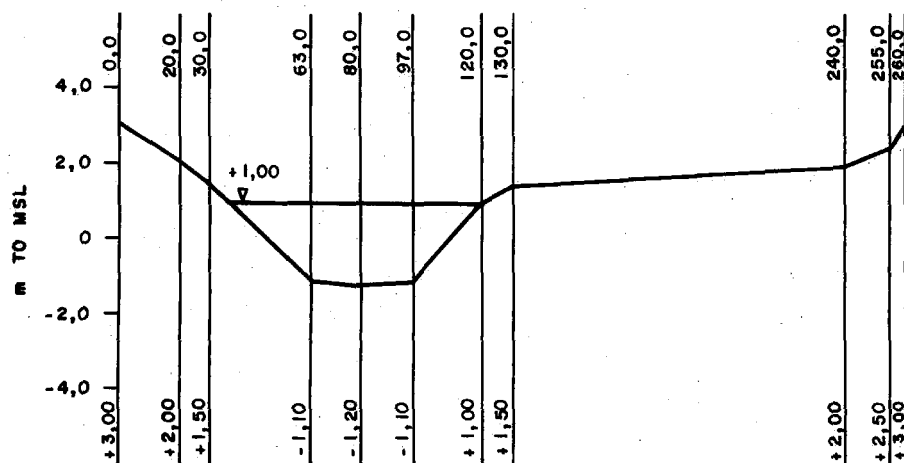
TRACED : JGAN
CHECKED :
DATE : JULY 1981
REF : C/SEA 8113

WILDERNESS NUMERICAL STUDY

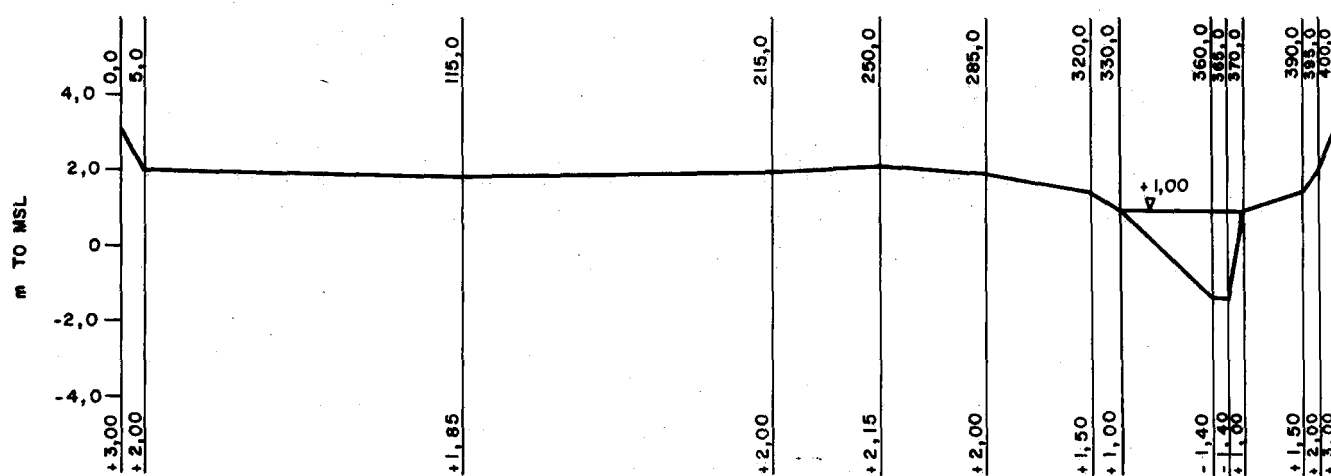
LAYOUT OF THE WILDERNESS LAKES
AND POSITIONS OF CROSS-SECTIONS

FIGURE
1b

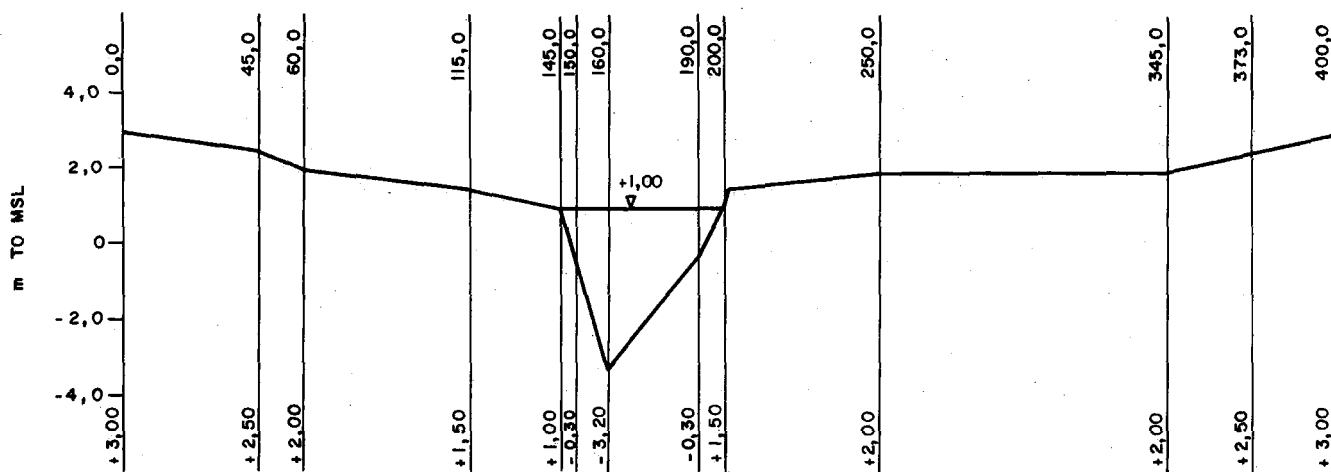




SECTION 1



SECTION 2

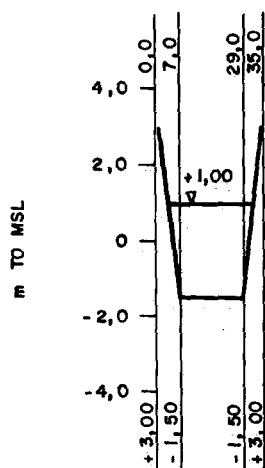
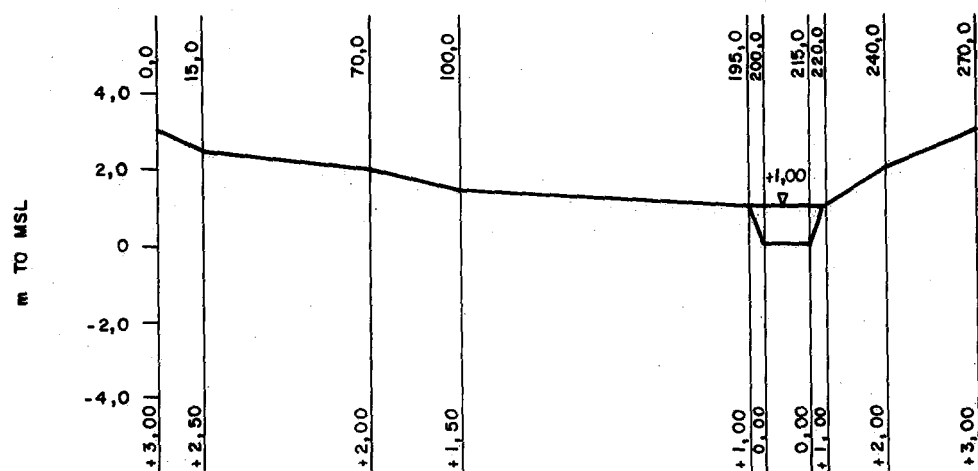
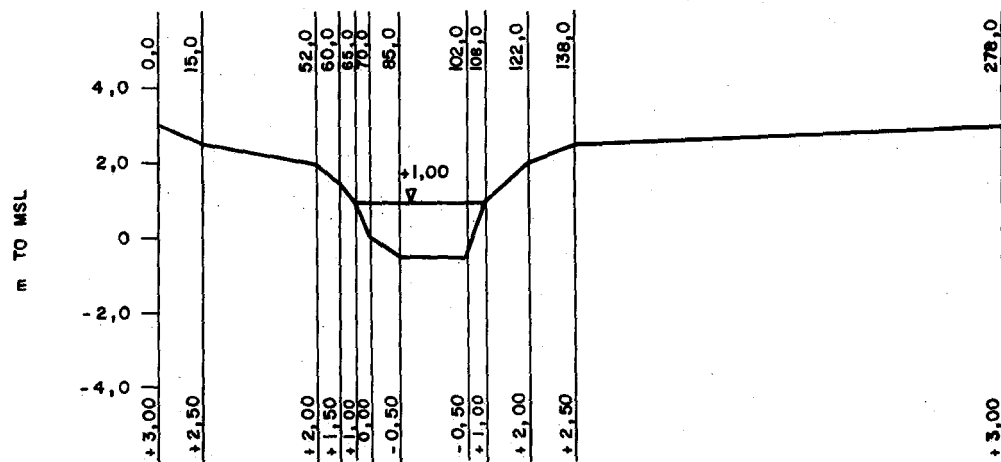


SECTION 3

TRACED JGAN
CHECKED:
DATE: JULY 1981
REF: C/SEA 8113

WILDERNESS NUMERICAL STUDY
CROSS-SECTIONAL SURVEYS

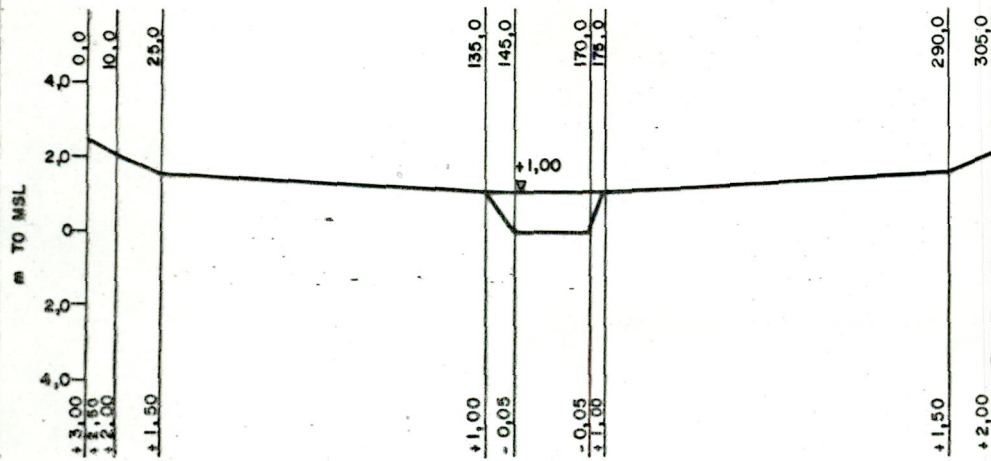
FIGURE
2.1a



TRACED: JGAN
 CHECKED:
 DATE: JULY 1981
 REF: C/SEP 8113

WILDERNESS NUMERICAL STUDY
 CROSS-SECTIONAL SURVEYS

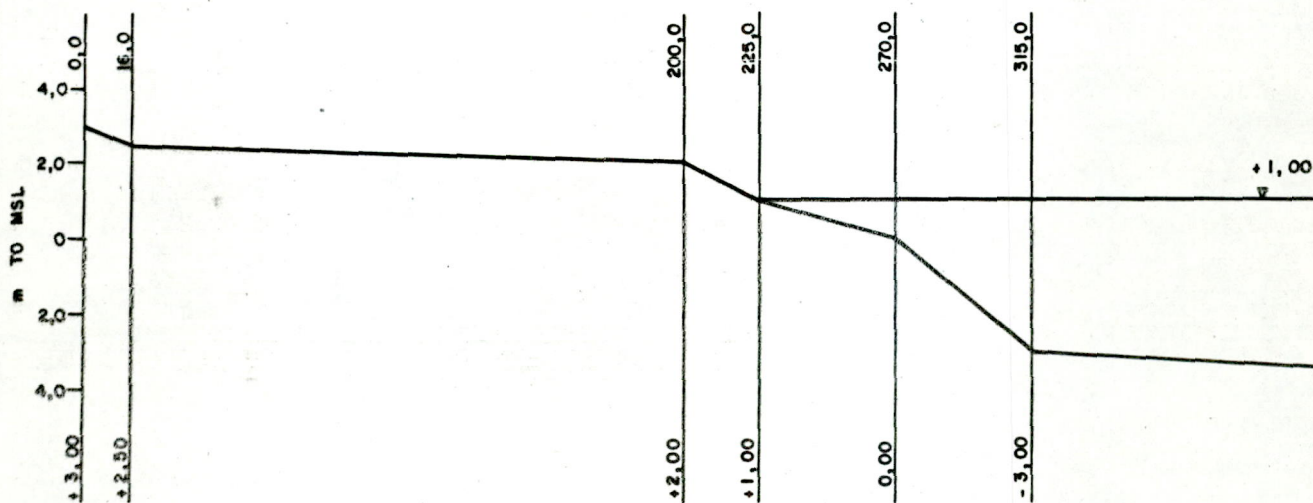
FIGURE
 2.1b



SECTION 6.1



SECTION 7

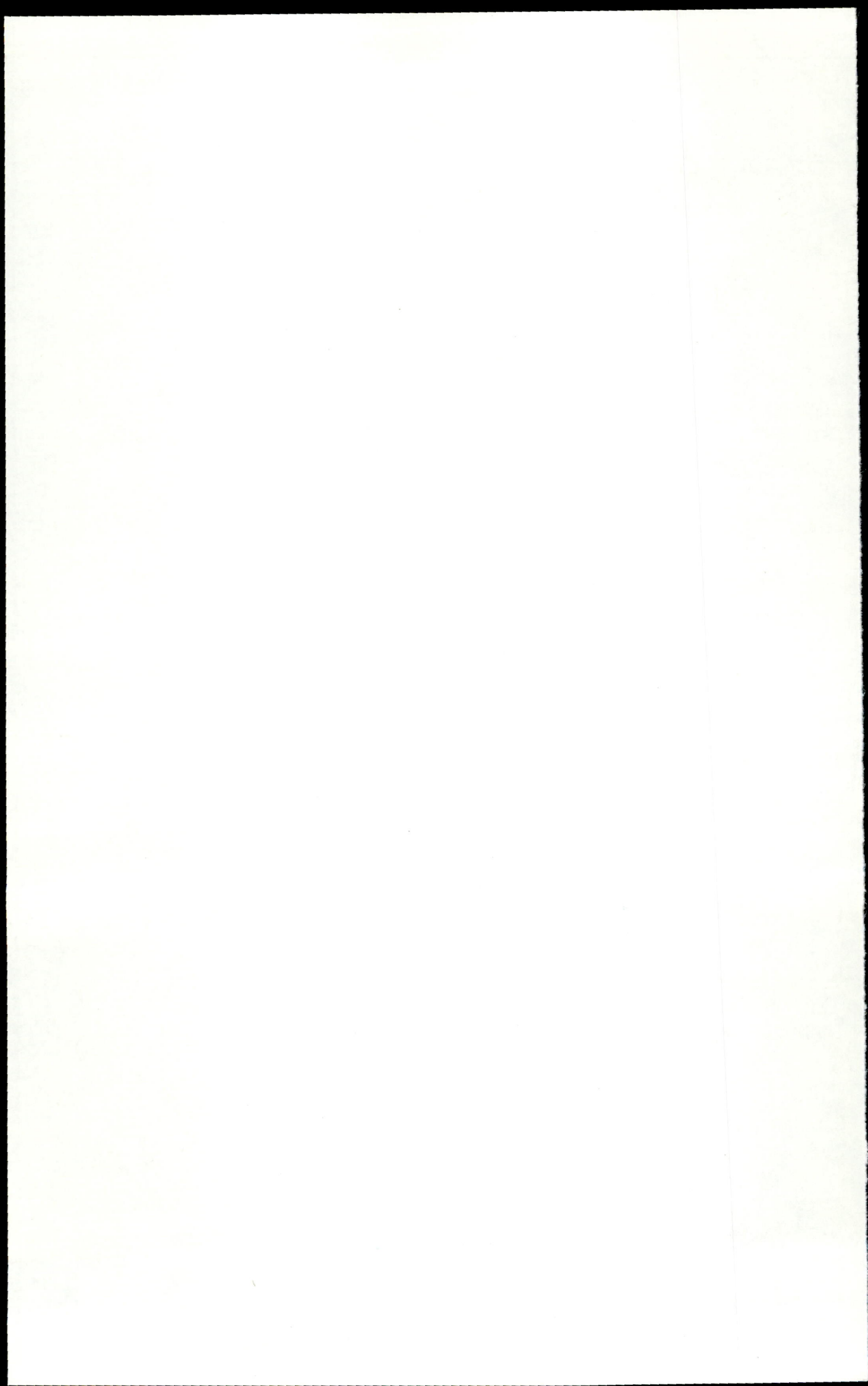


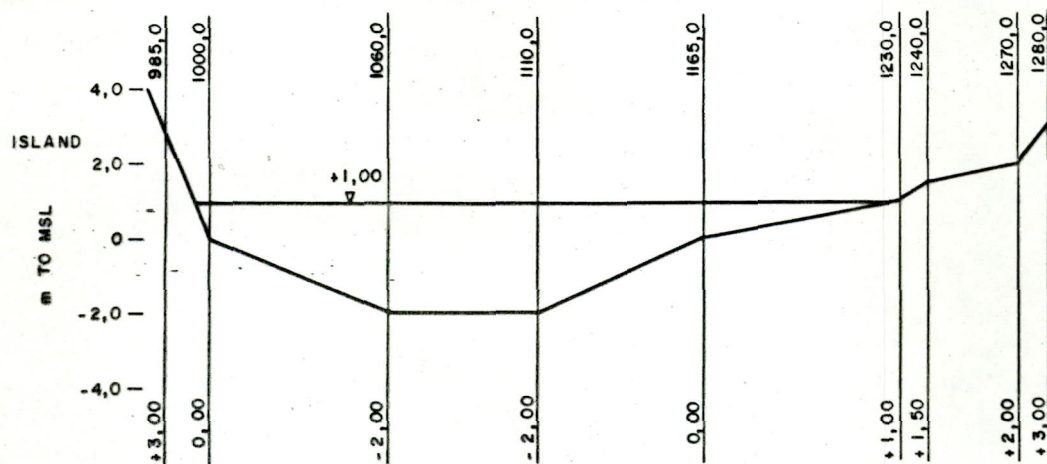
SECTION 8

TRACED : JGAN
CHECKED :
DATE : July 1981
REF : C/SEA 113

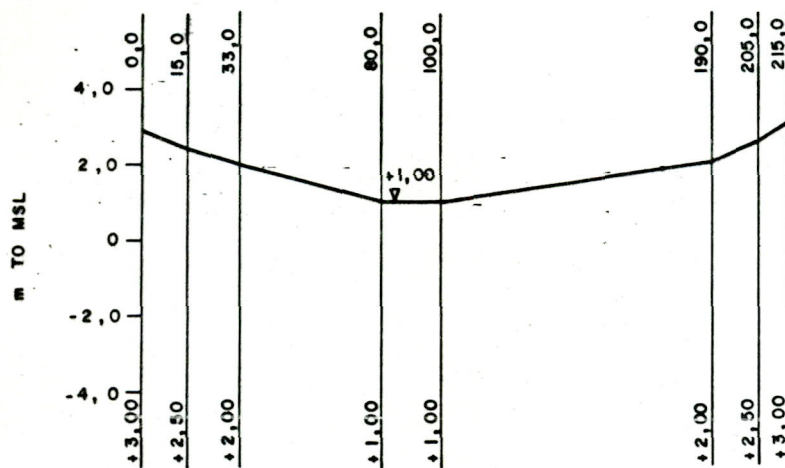
WILDERNESS NUMERICAL STUDY
CROSS-SECTIONAL SURVEYS

FIGURE
2.1c

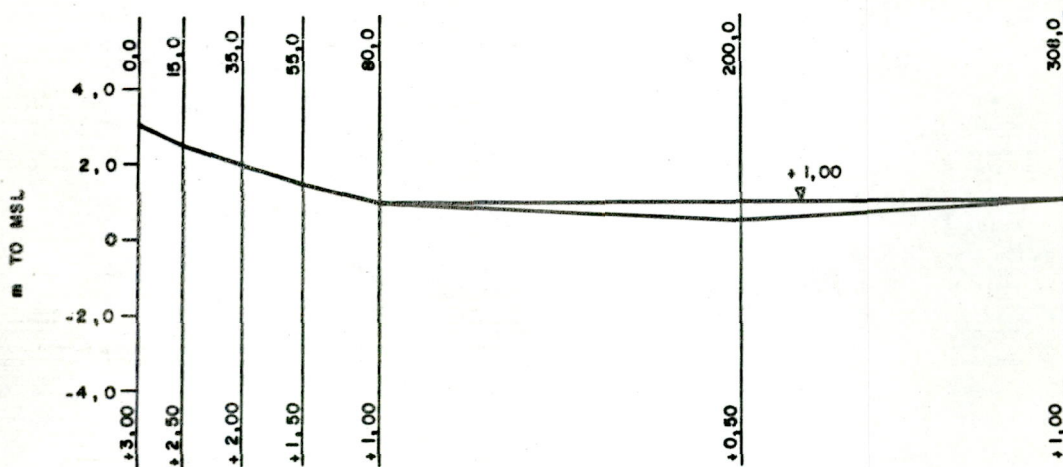




SECTION 8 CONTINUE



SECTION 9

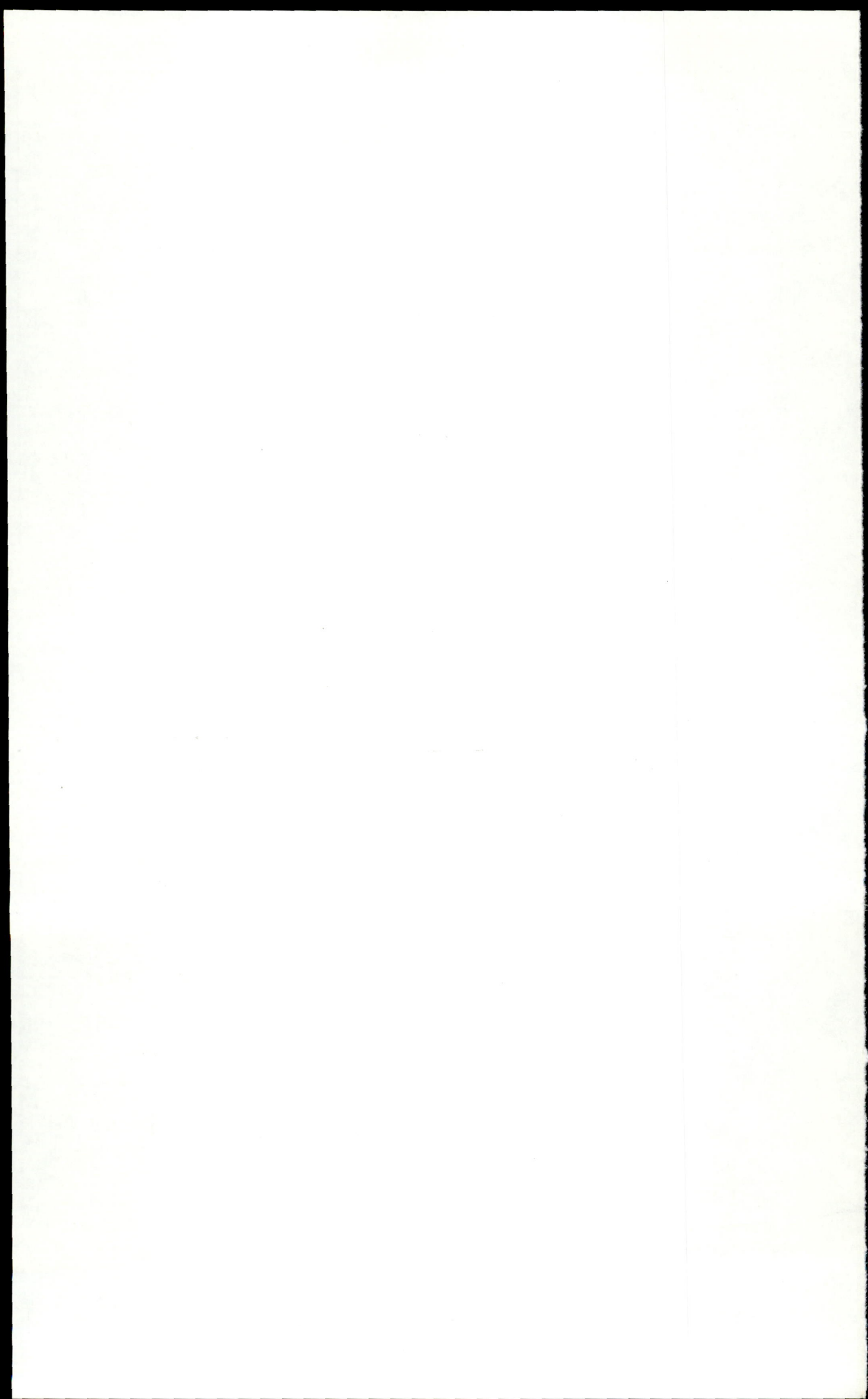


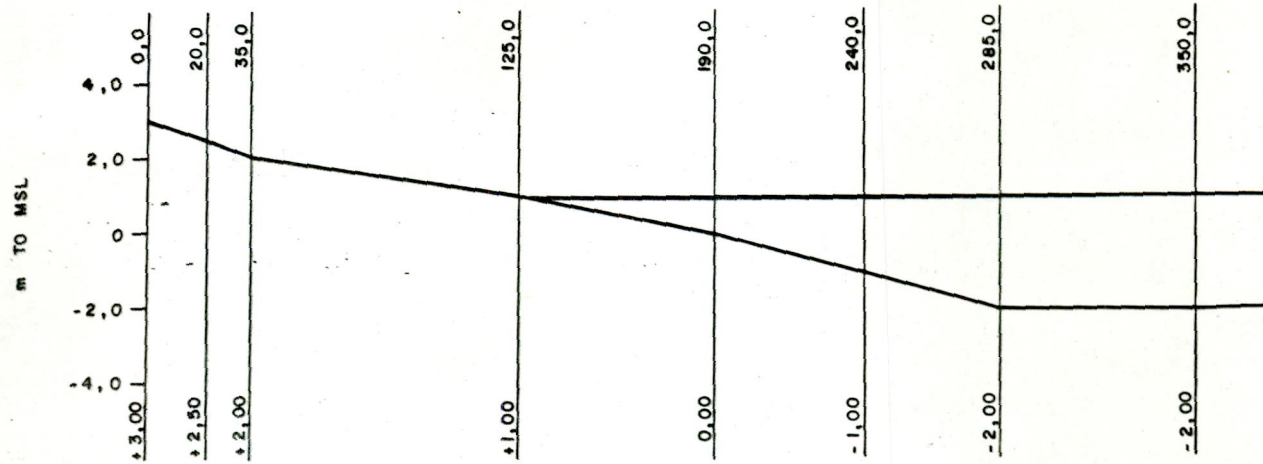
SECTION 10

TRACED : JGAN
 CHECKED :
 DATE : JULY 1981
 REF : C/SEA 8113

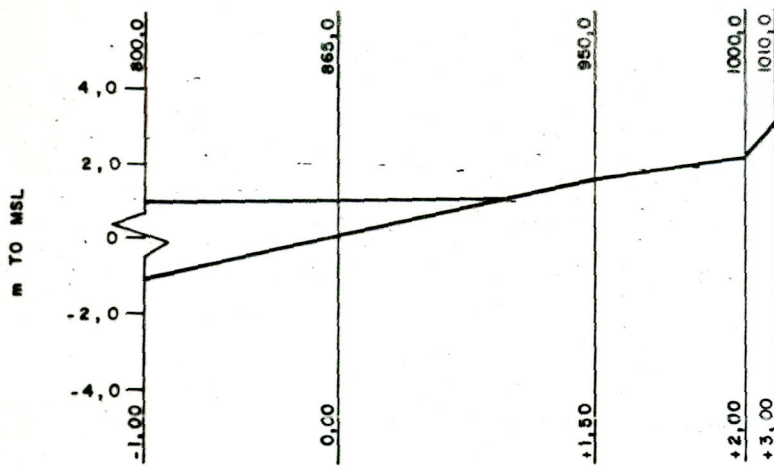
WILDERNESS NUMERICAL STUDY
 CROSS-SECTIONAL SURVEYS

FIGURE
 2.1d

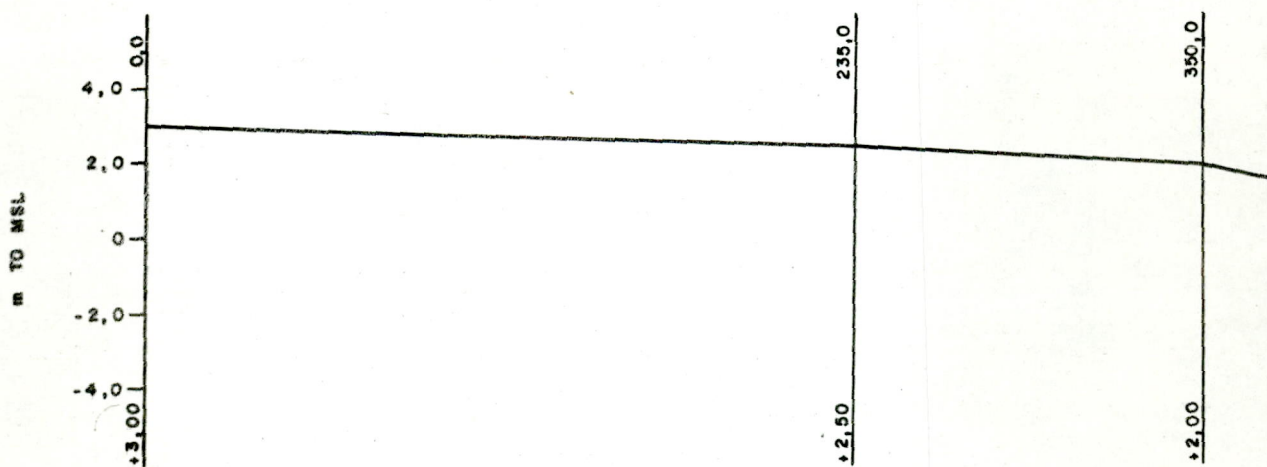




SECTION II



SECTION II CONTINUE



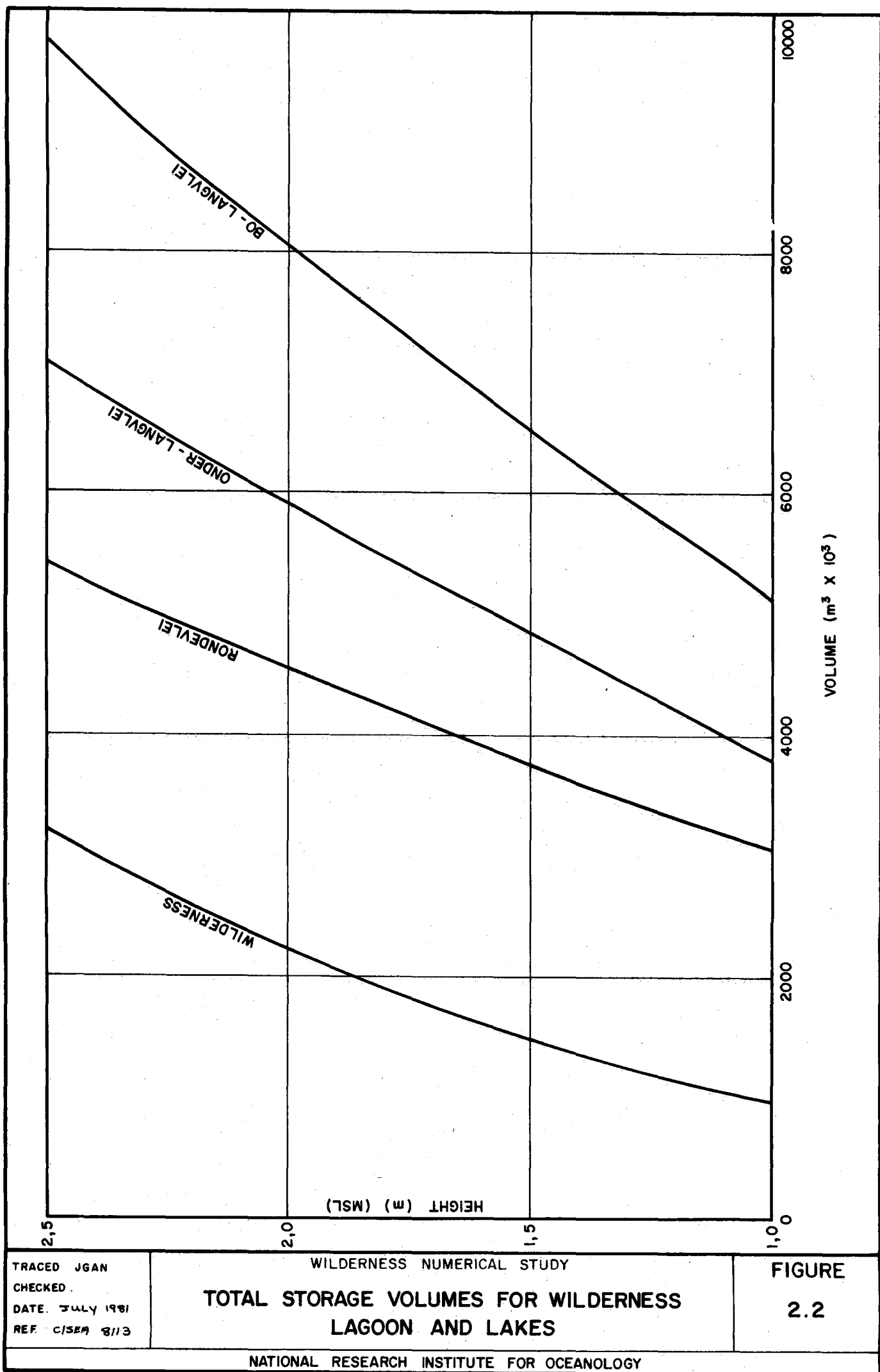
SECTION 12

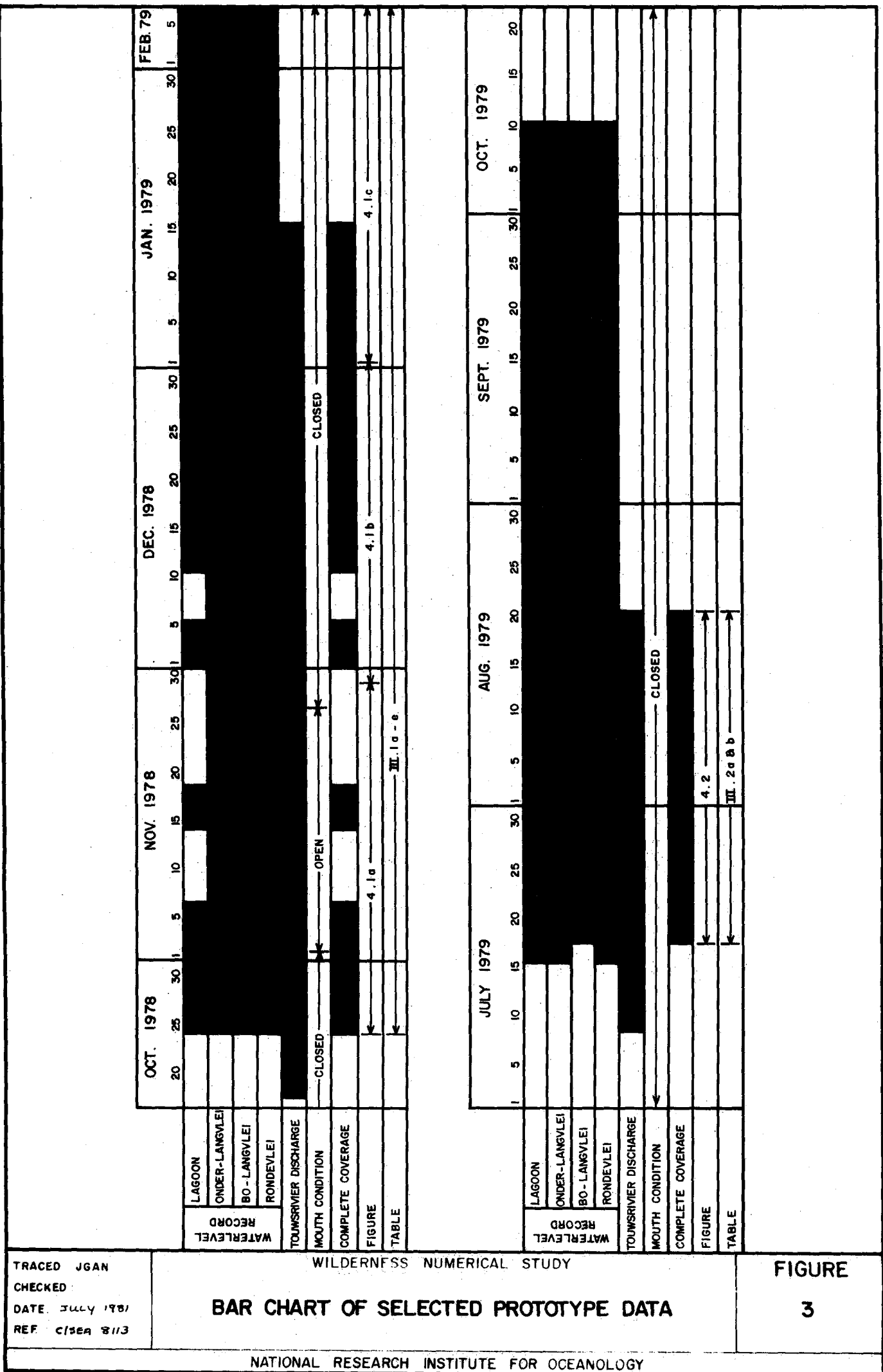
TRACED : JGAN
 CHECKED:
 DATE: JULY 1981
 REF: CISEA 8113

WILDERNESS NUMERICAL STUDY
 CROSS-SECTIONAL SURVEYS

FIGURE
 2.1e



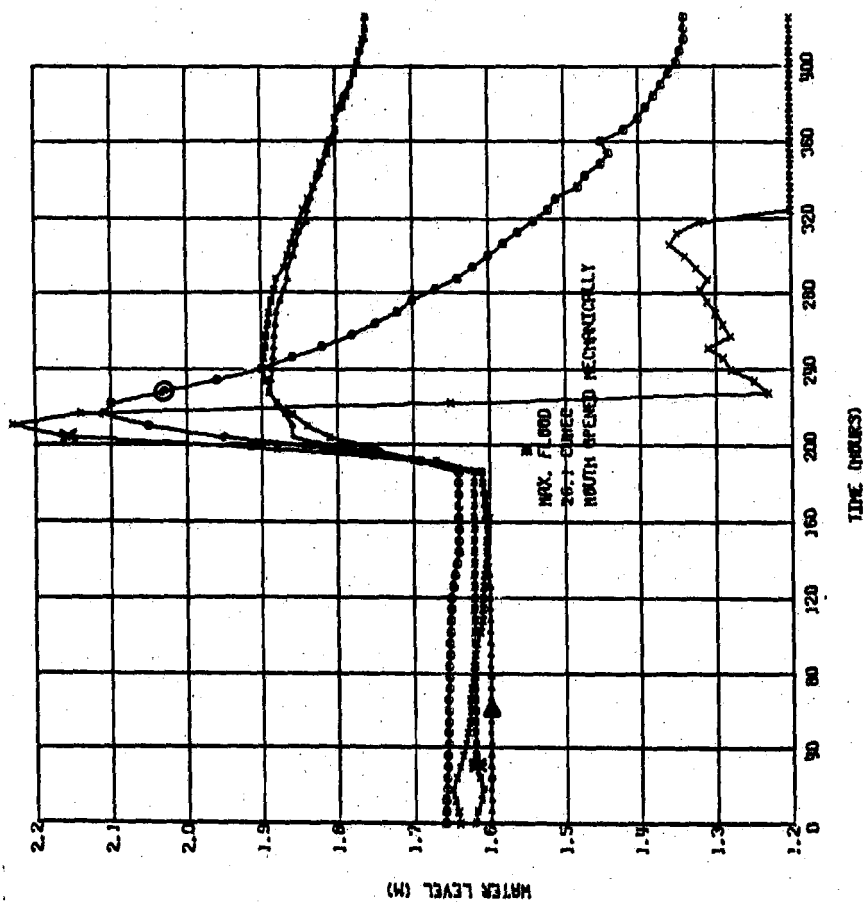




TRACED JGAN
 CHECKED
 DATE July 1981
 REF C13EA 8113

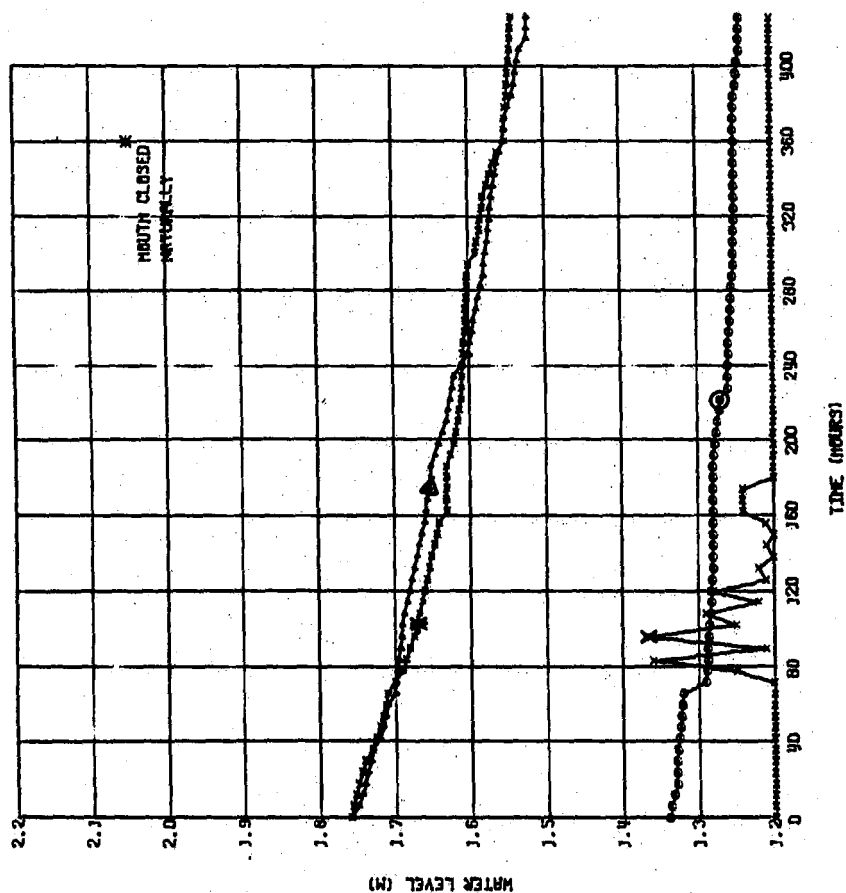
BAR CHART OF SELECTED PROTOTYPE DATA

FIGURE
 3



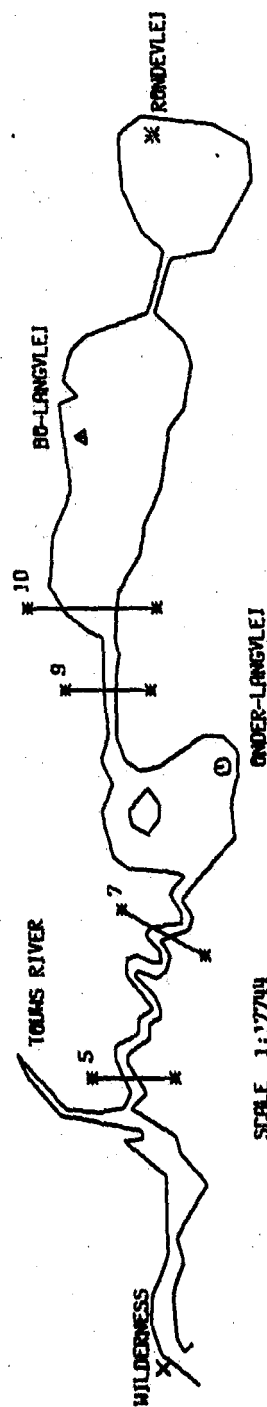
PROTOTYPE DATA.

PERIOD : 25/10/1978 (0000) TO 11/11/1978 (1200)



PROTOTYPE DATA.

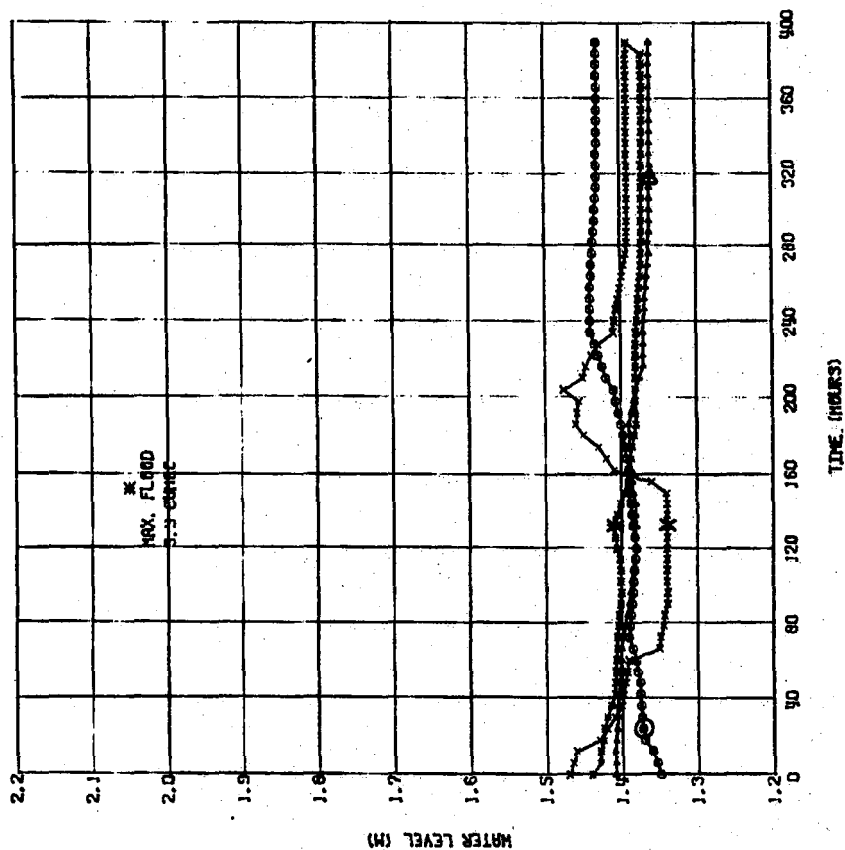
PERIOD : 11/11/1978 (1800) TO 29/11/1978 (1200)



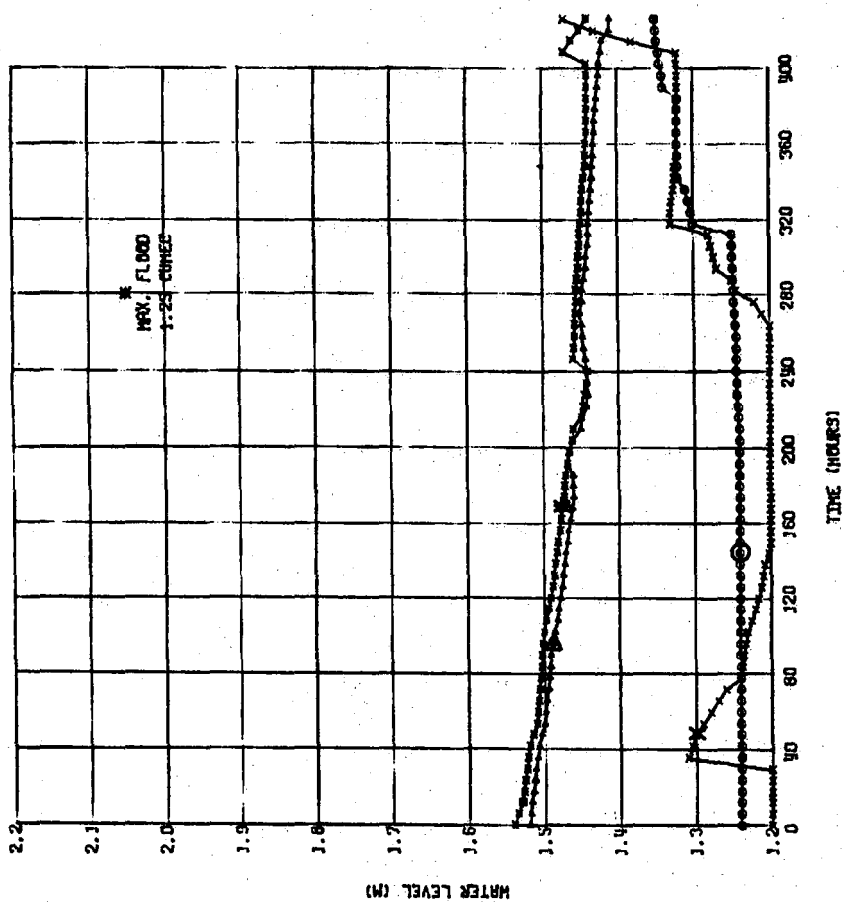
TRACED : COMLOT
CHECKED :
DATE : 1980-08-30
REF. : C/SEM 8113

WILDERNESS NUMERICAL STUDY
PROTOTYPE DATA.
25/10/1978 TO 29/11/1978.

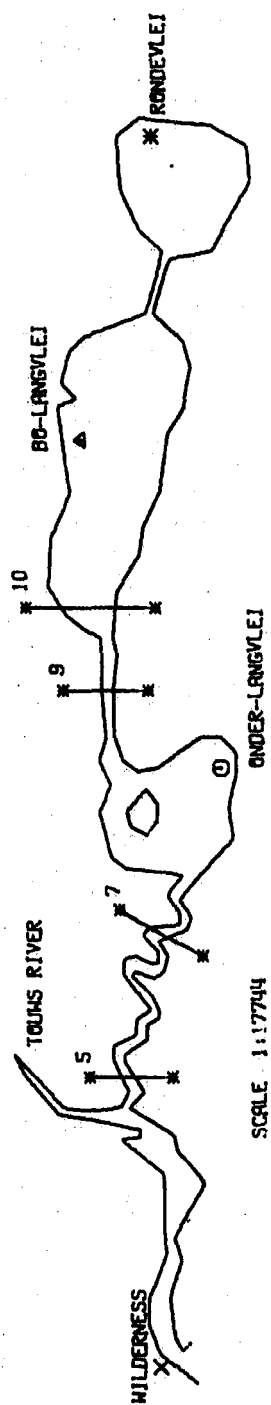
FIGURE
4.10



PROTOTYPE DATA.
PERIOD : 17/12/1978 (0400) TO 1/1/1979 (0600)



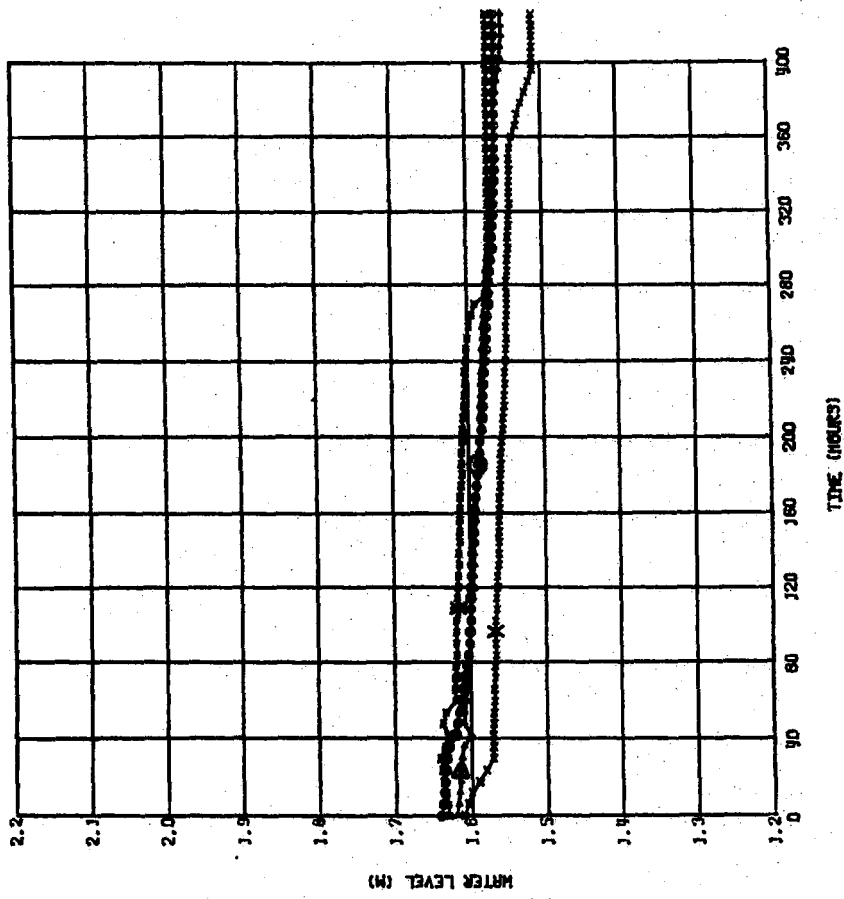
PROTOTYPE DATA.
PERIOD : 29/11/1978 (1200) TO 17/12/1978 (0400)



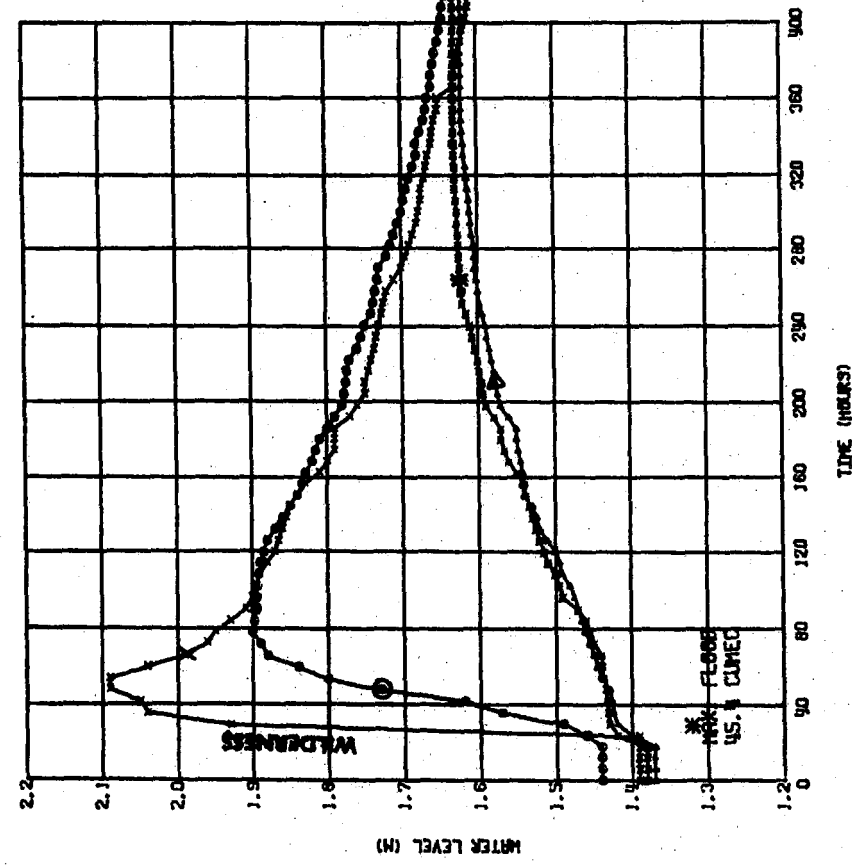
TRACED : COMPT
CHECKED :
DATE : 1980-08-30
REF. : c/sen 3113

WILDERNESS NUMERICAL STUDY
PROTOTYPE DATA.
29/11/1978 TO 1/1/1979.

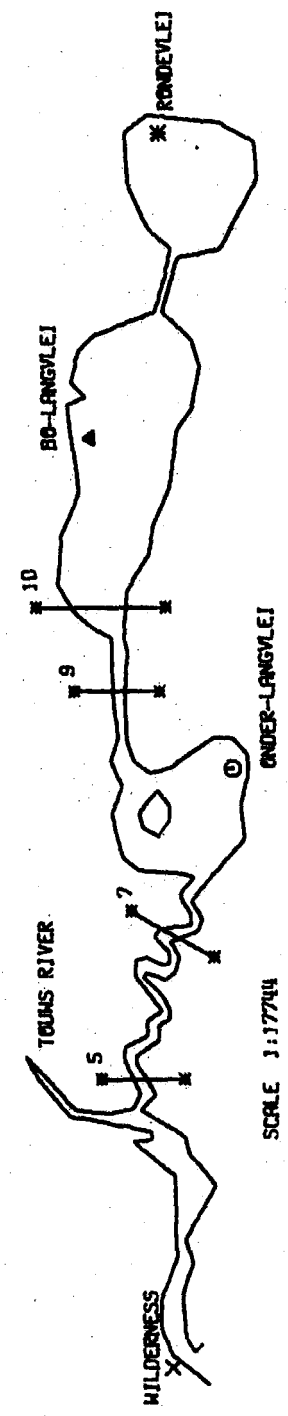
FIGURE
4.1b



PROTOTYPE DATA.
PERIOD : 1/1/1979 (1200) TO 19/1/1979 (6H00)



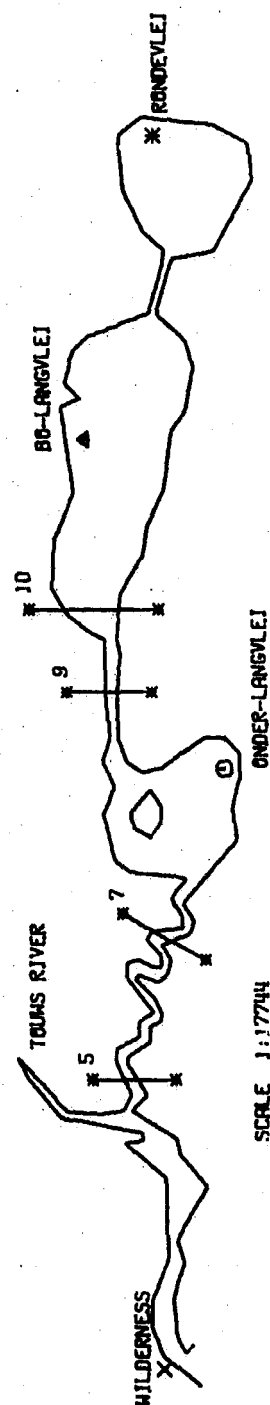
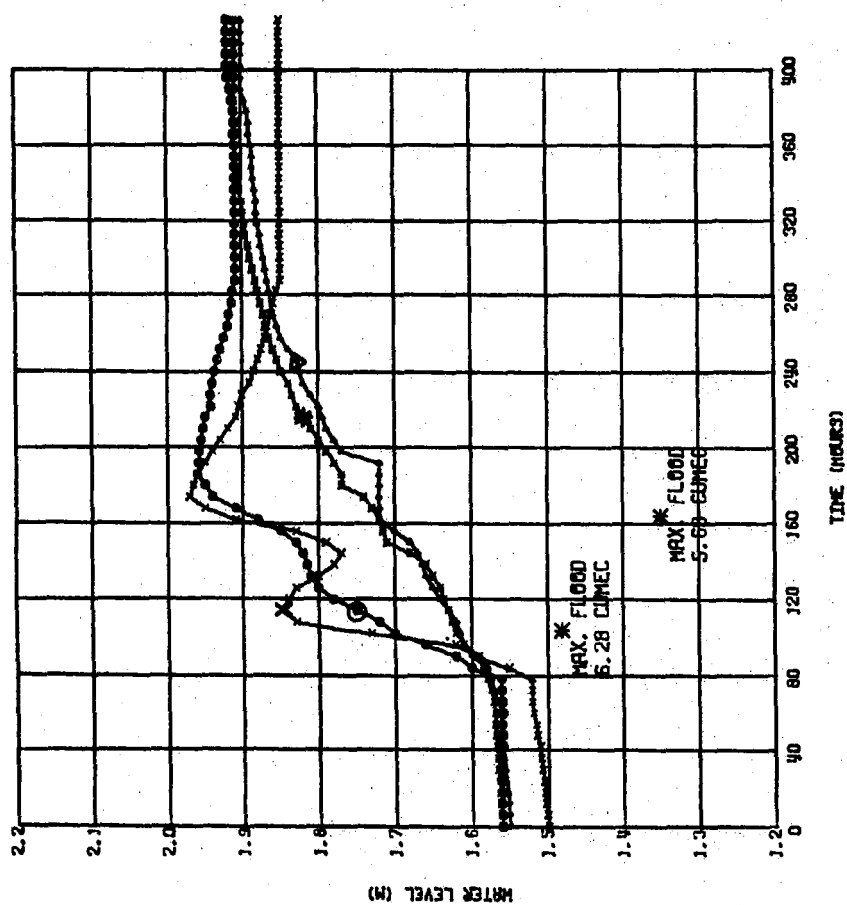
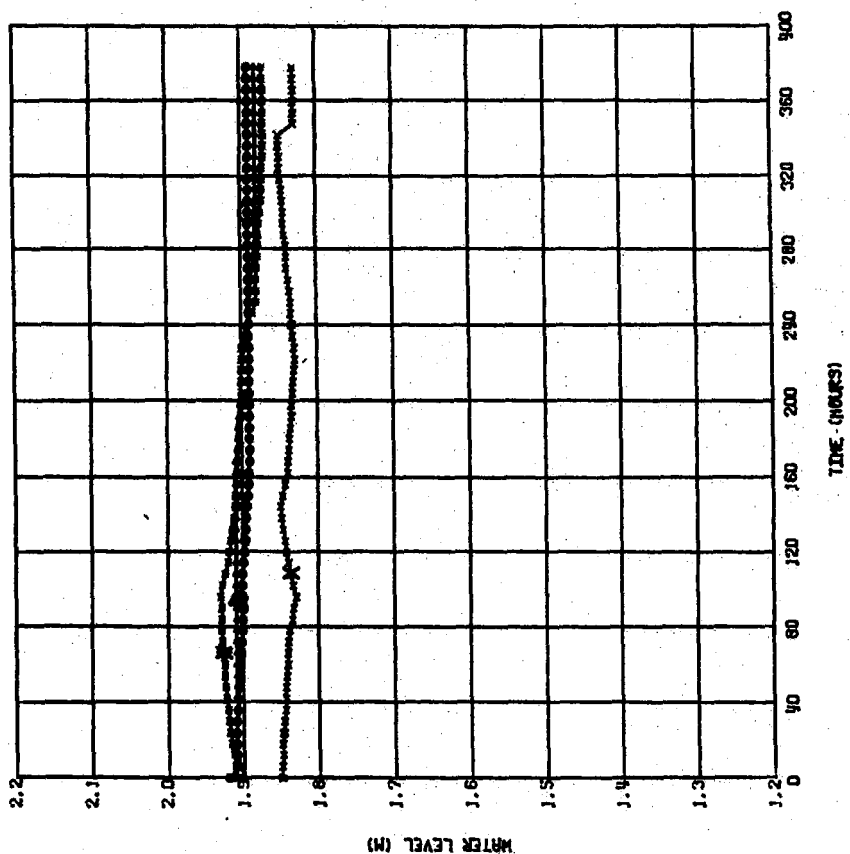
PROTOTYPE DATA.
PERIOD : 1/1/1979 (1200) TO 19/1/1979 (6H00)



TRACED : COMLOT
CHECKED :
DATE : 1980-08-30
REF. : C/SEN 8113

WILDERNESS NUMERICAL STUDY
PROTOTYPE DATA.
1/1/1979 TO 6/2/1979.

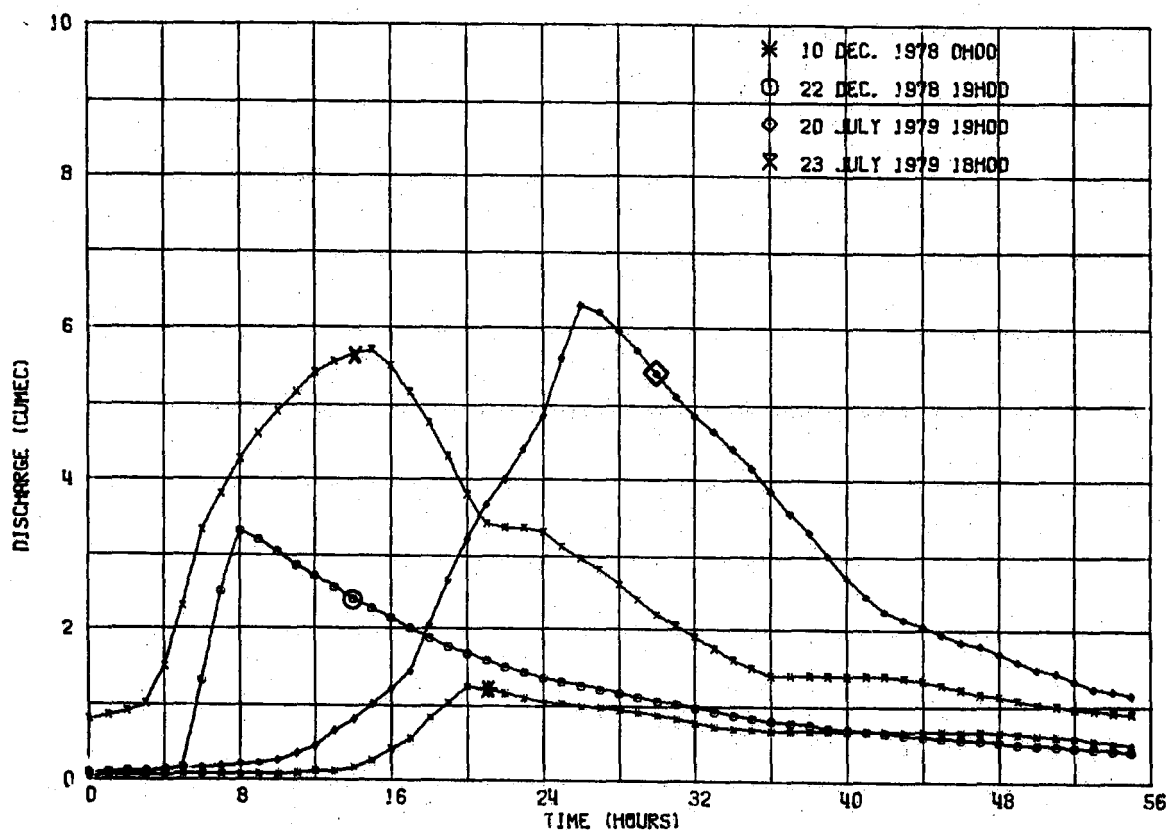
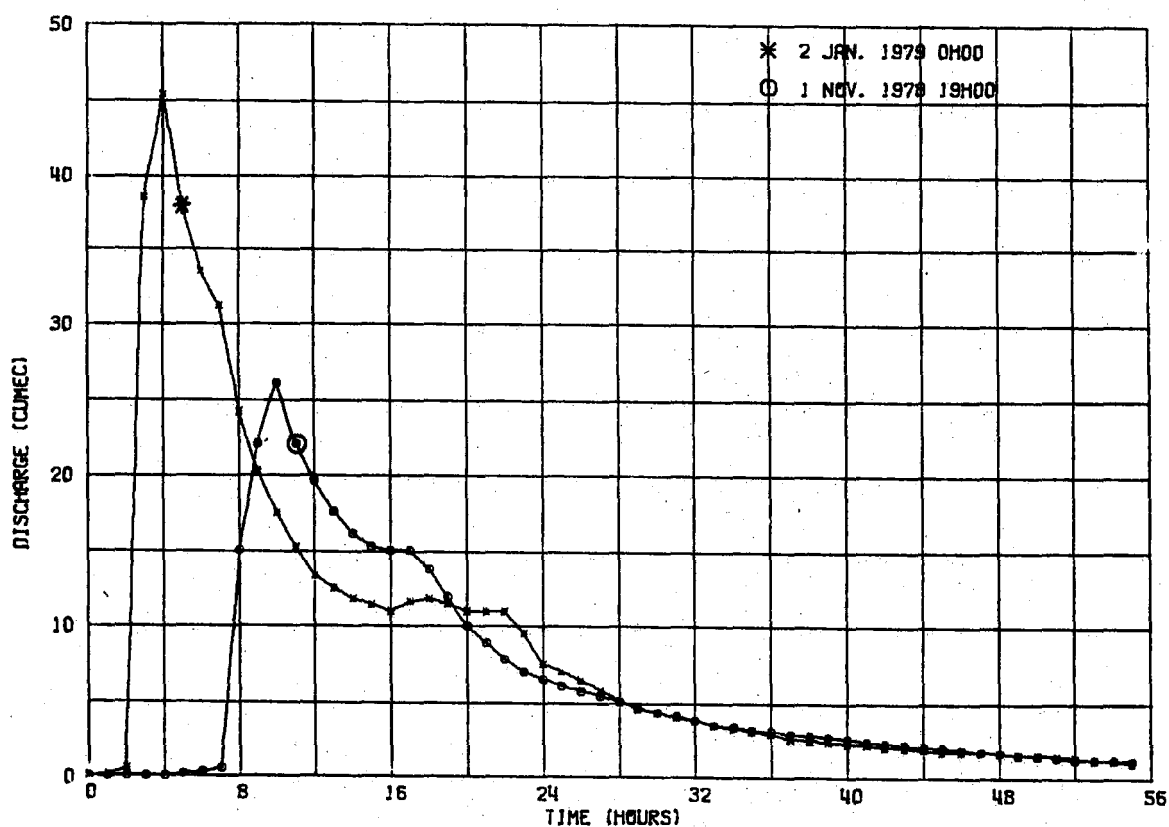
FIGURE
4.1c



TRACED : COMLOT
CHECKED :
DATE : 1980-08-30
REF. : C/SEA 8113

WILDERNESS NUMERICAL STUDY
PROTOTYPE DATA.
17/7/1979 TO 20/8/1979.

FIGURE
4.2



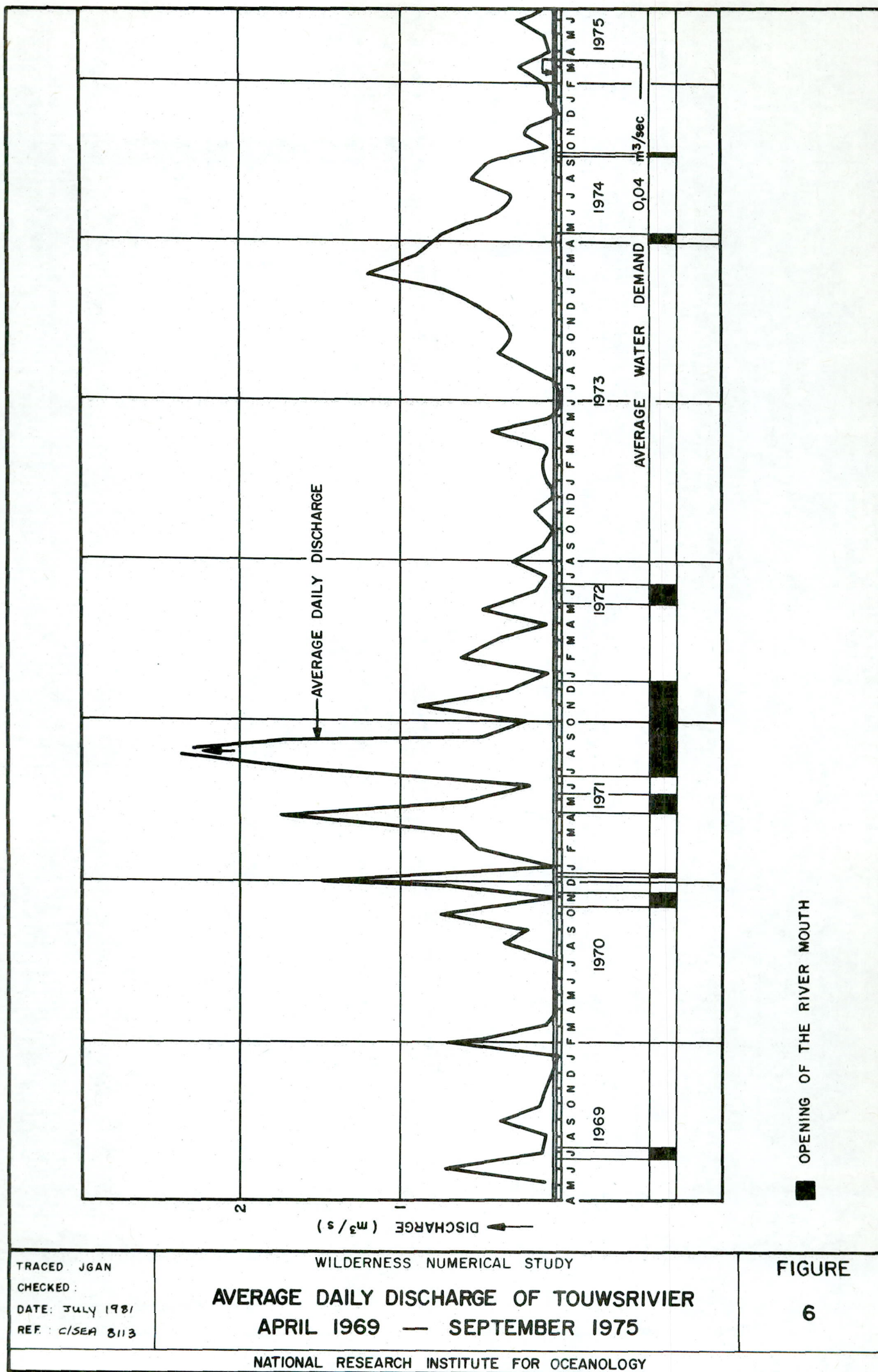
MEASURED BY THE DEPARTMENT OF WATER AFFAIRS
BY MEANS OF A WATER LEVEL GAUGE.

TRACED : COMLOT
CHECKED :
DATE : 1980-08-30
REF. : C/SEA 8113

WILDERNESS NUMERICAL STUDY
PROTOTYPE DATA.
TOUWS RIVER DISCHARGES.

FIGURE
5

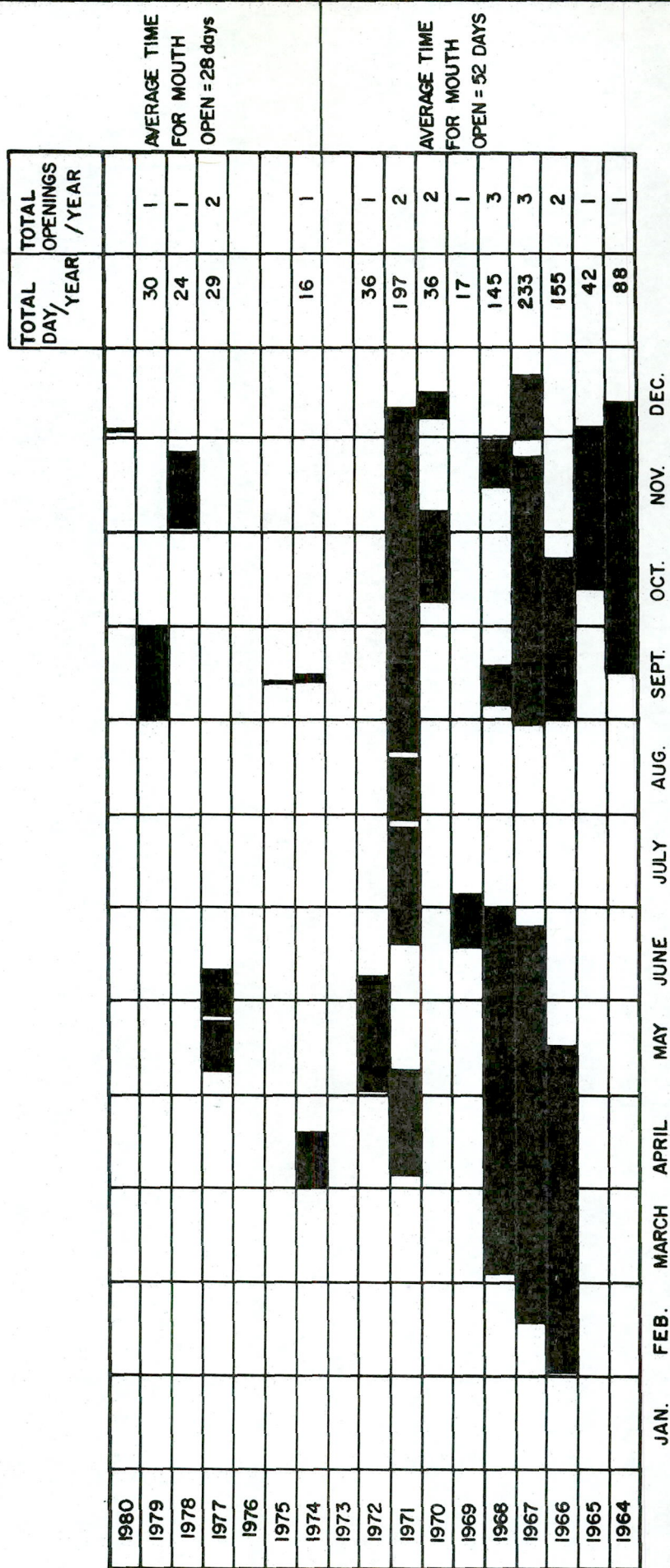
NATIONAL RESEARCH INSTITUTE FOR OCEANOLOGY



TRACED JGAN
 CHECKED :
 DATE: July 1981
 REF: C/SEA 8113

WILDERNESS NUMERICAL STUDY
AVERAGE DAILY DISCHARGE OF TOUWSRIVIER
APRIL 1969 — SEPTEMBER 1975

FIGURE
6



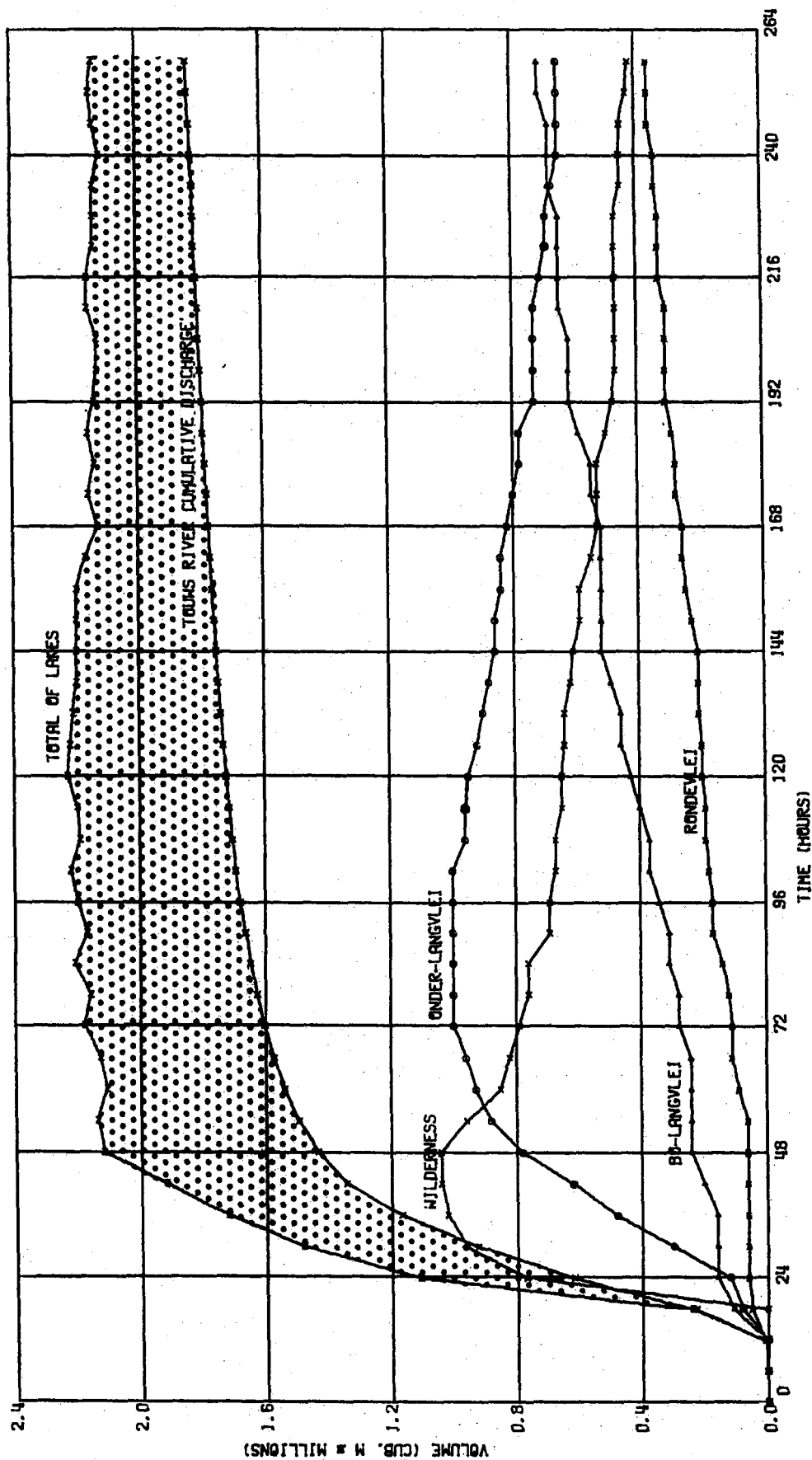
OPEN

TRACED JGAN
 CHECKED:
 DATE: July 1981
 REF C/SEA 8113

WILDERNESS NUMERICAL STUDY

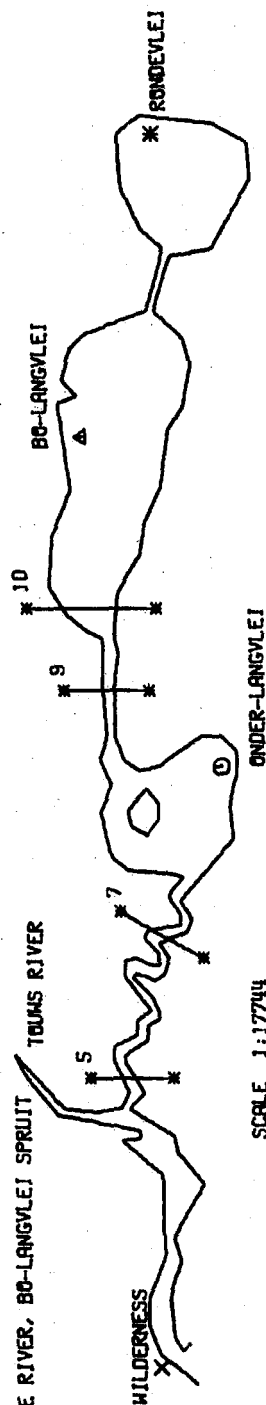
CONDITIONS OF TOUWSRIVIER MOUTH
 (1964 - 1980)

FIGURE
 7



LEGEND

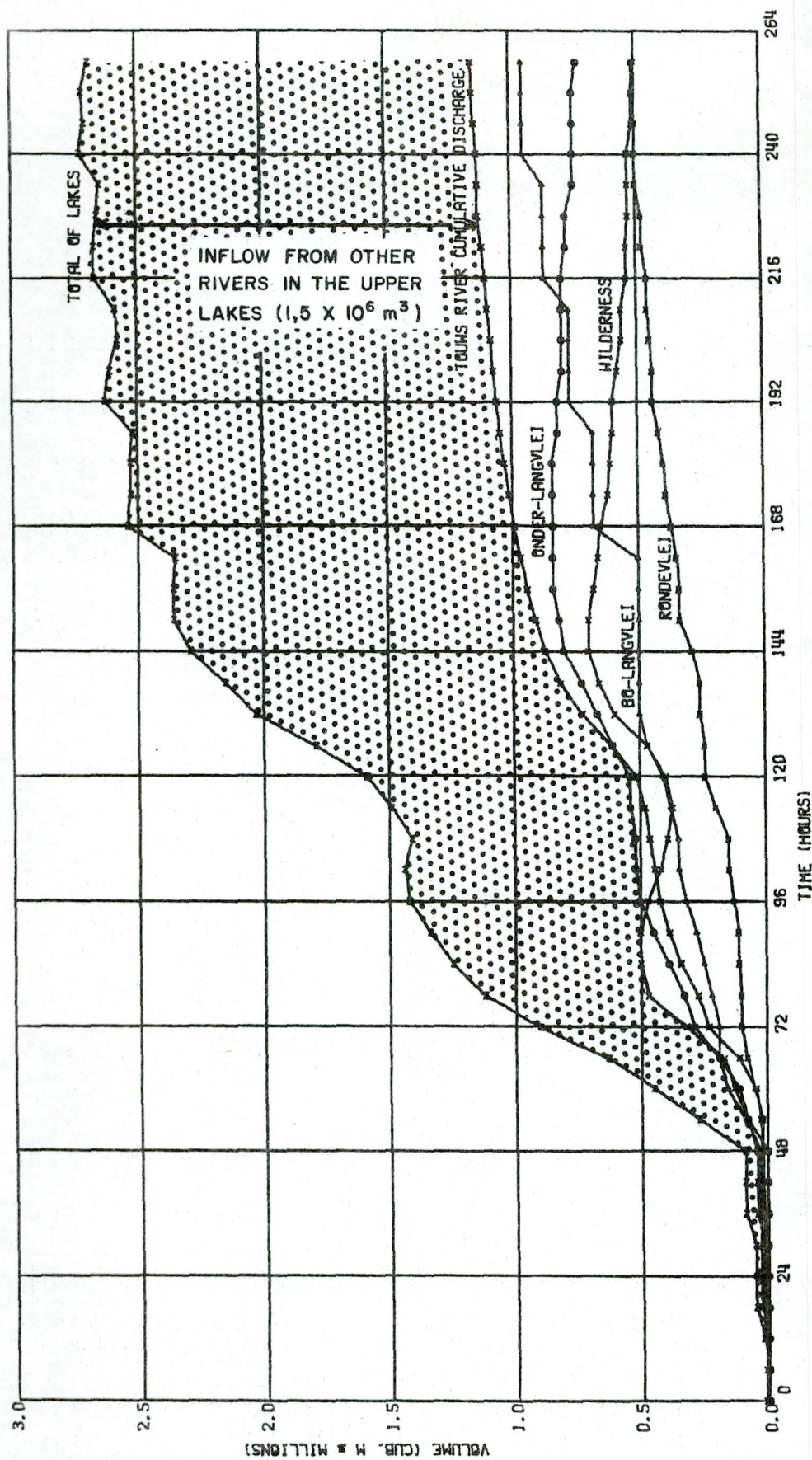
 VOLUME DUE TO RAINFALL, OUIJE RIVER, BO-LANGVLEI SPRUIT
AND OTHER RIVULETS.



TRACED : COMPILOT
CHECKED :
DATE : 1980-08-30
REF. : C/SEA 8113

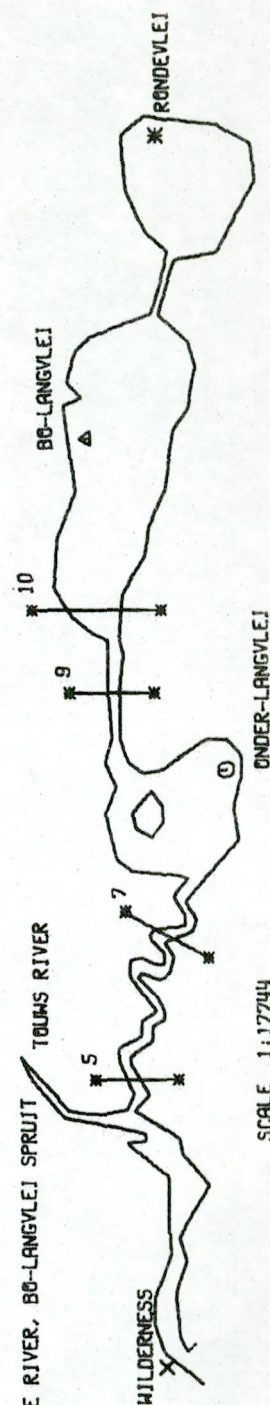
WILDERNESS NUMERICAL STUDY
VOLUME CHANGES OF LAKES AND TOTAL
DISCHARGE OF TOUWS RIVER (JAN. 1979)

FIGURE
8a



LEGEND

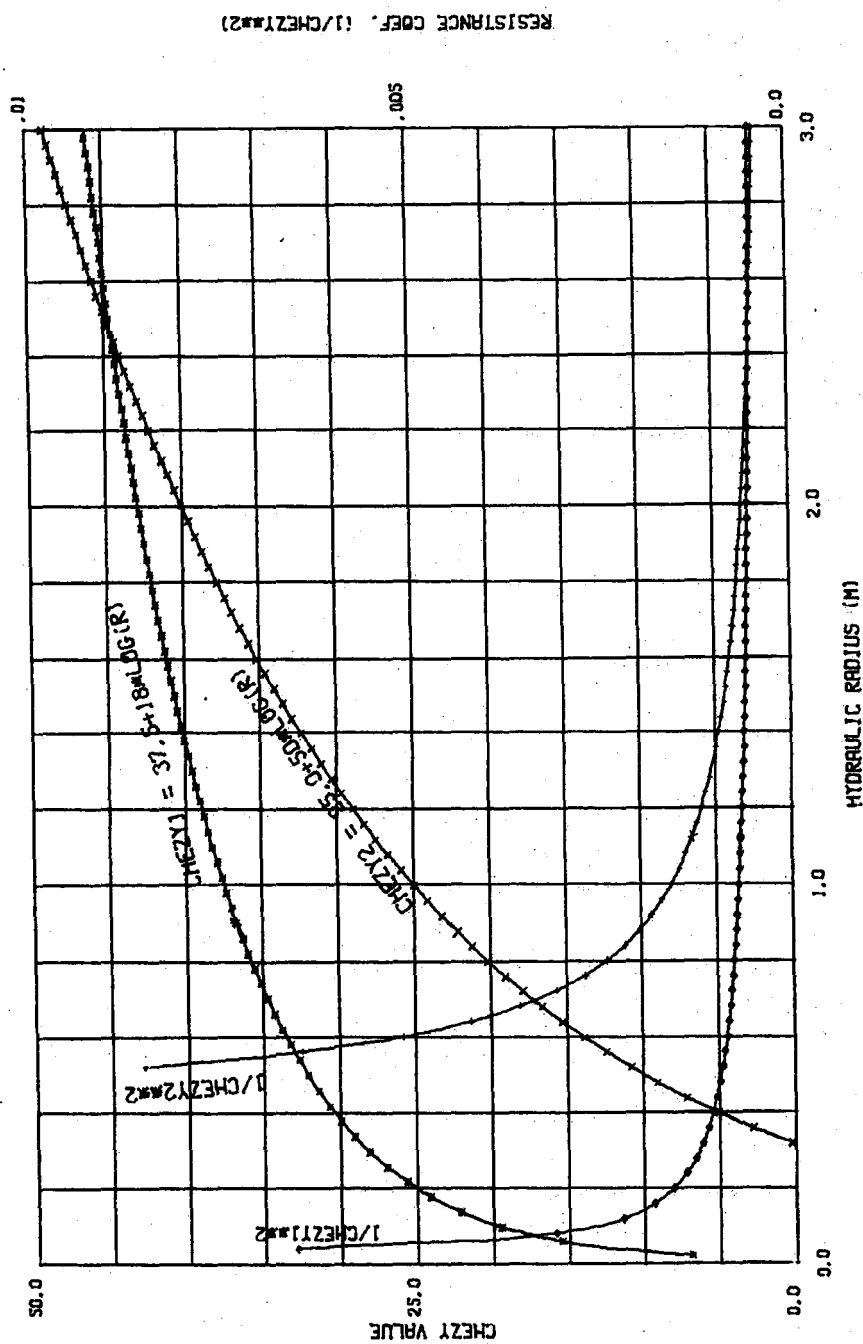
 VOLUME DUE TO RAINFALL, DUJME RIVER, BO-LANGVEIJ SPRUIT AND OTHER RIVULETS.



TRACED : COMPLIT
CHECKED :
DATE : 1980-08-30
REF. : C/SEA 8113

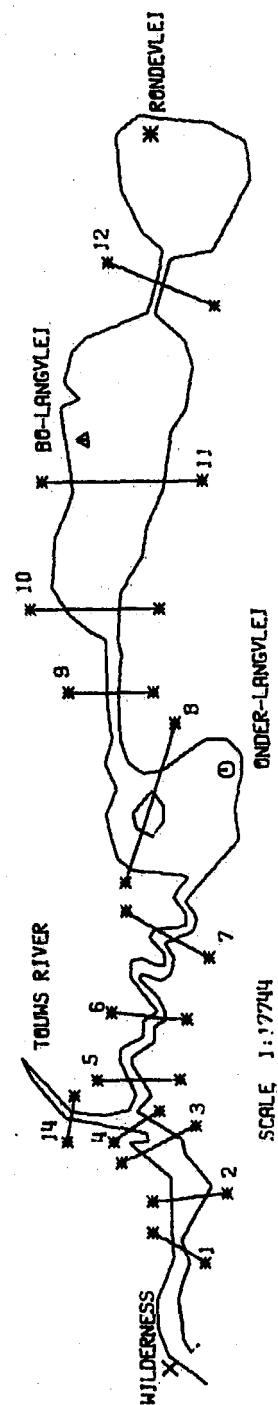
WILDERNESS NUMERICAL STUDY
VOLUME CHANGES OF LAKES AND TOTAL
DISCHARGE OF TOUWS RIVER (JULY 1979)

FIGURE
8b



CHEZY1 : RESISTANCE FOR SECTIONS 1,2,3,4,8,11 AND 14.

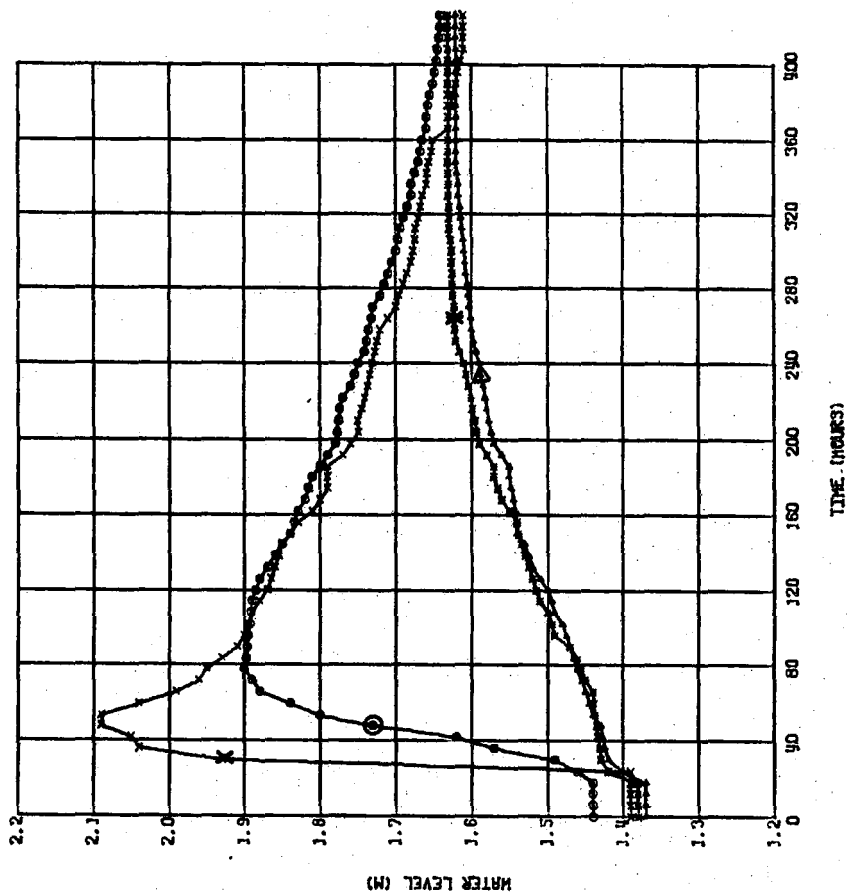
CHEZY2 : RESISTANCE FOR SECTIONS 5,6,7,9,10 AND 12.



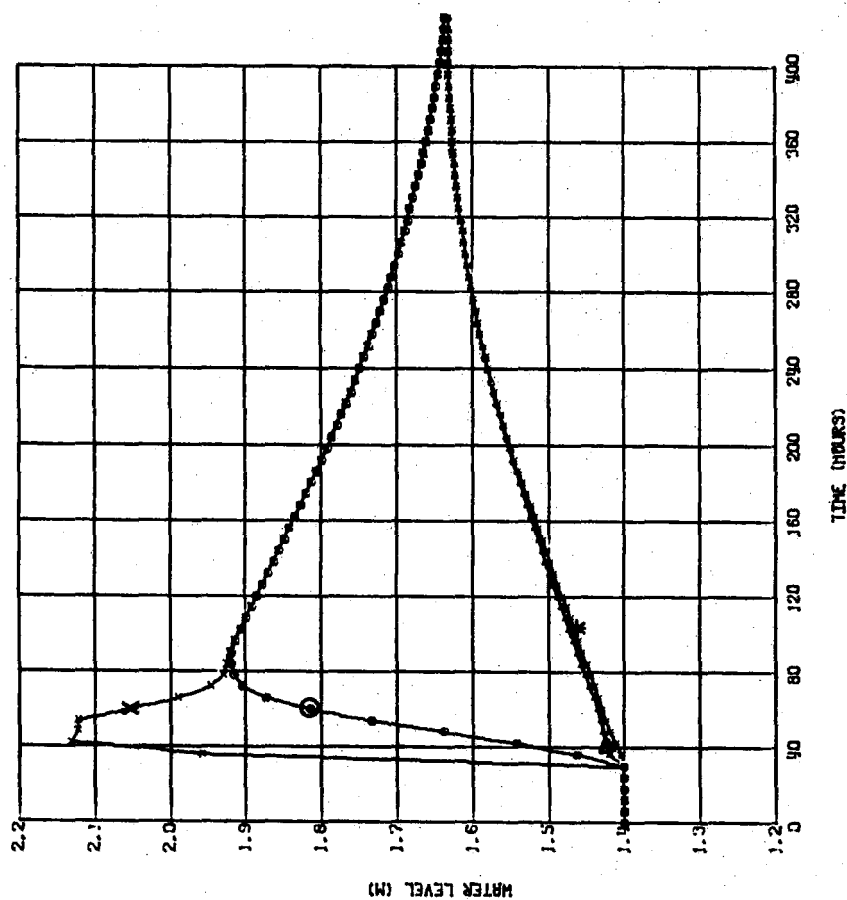
TRACED : COMPLIT
CHECKED :
DATE : 1980-08-30
REF. : C/SEA 3113

WILDERNESS NUMERICAL STUDY
RESISTANCE FOR WILDERNESS MODEL.
CHEZY COEFFICIENTS.

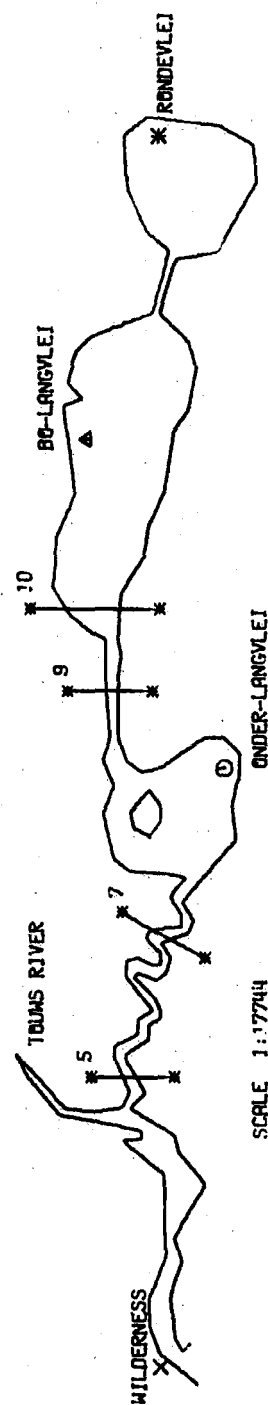
FIGURE
9



PROTOTYPE DATA.
ORIGINAL LAYOUT.
FLOOD : JANUARY 1979 INITIAL LEVEL : 1.4 M



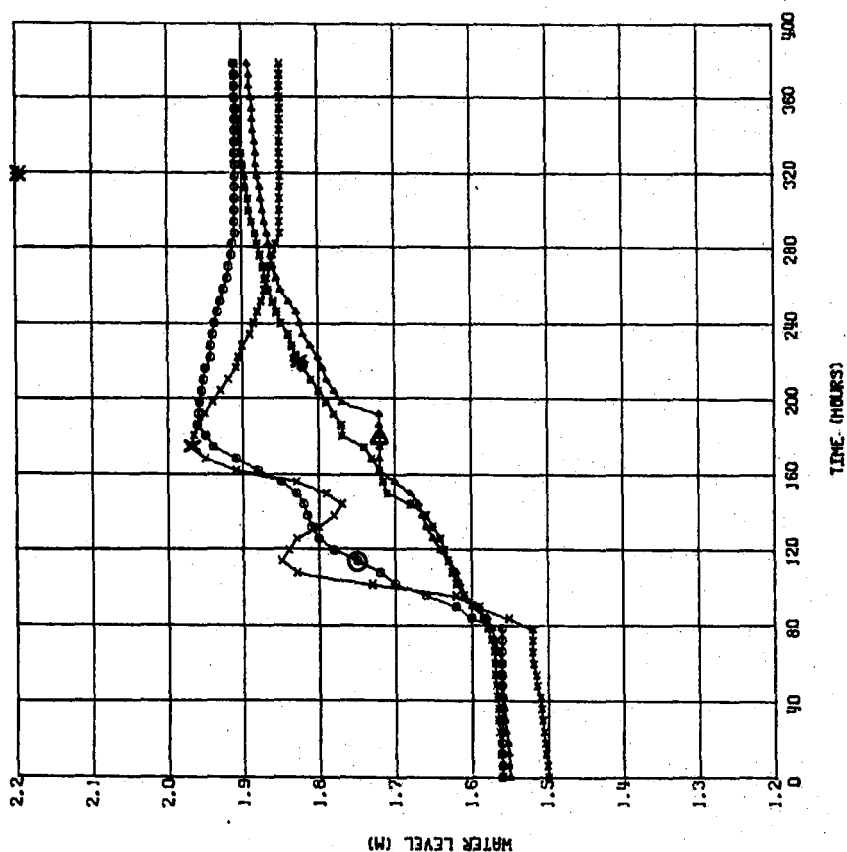
MODEL RESULTS
ORIGINAL LAYOUT
FLOOD : JANUARY 1979 INITIAL LEVEL : 1.4 M



TRACED : COMLOT
CHECKED :
DATE : 1980-08-30
REF. : C/SEA 8113

WILDERNESS NUMERICAL STUDY
MODEL CALIBRATION
PROTOTYPE DATA - JANUARY 1979.

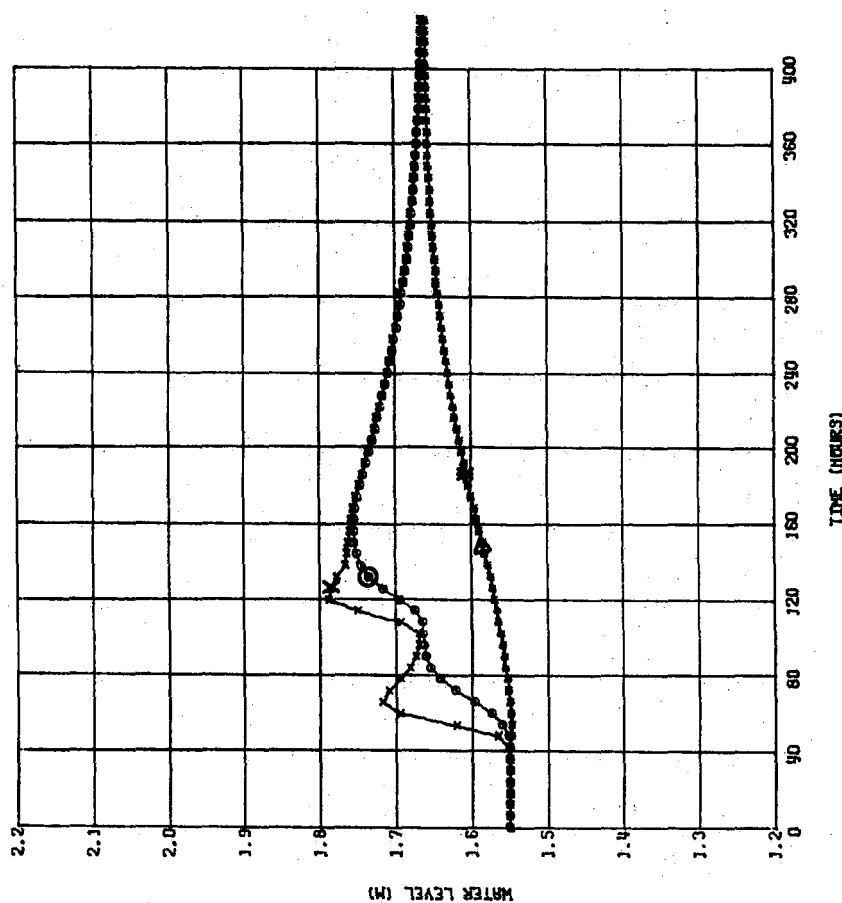
FIGURE
10a



PROTOTYPE DATA.

ORIGINAL LAYOUT.

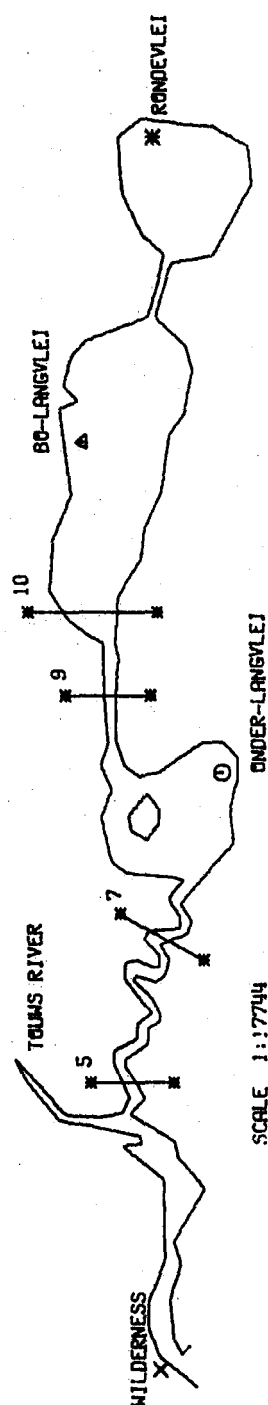
FLOOD : JULY 1979. INITIAL LEVEL 1.55 M.



MODEL RESULTS.

ORIGINAL LAYOUT.

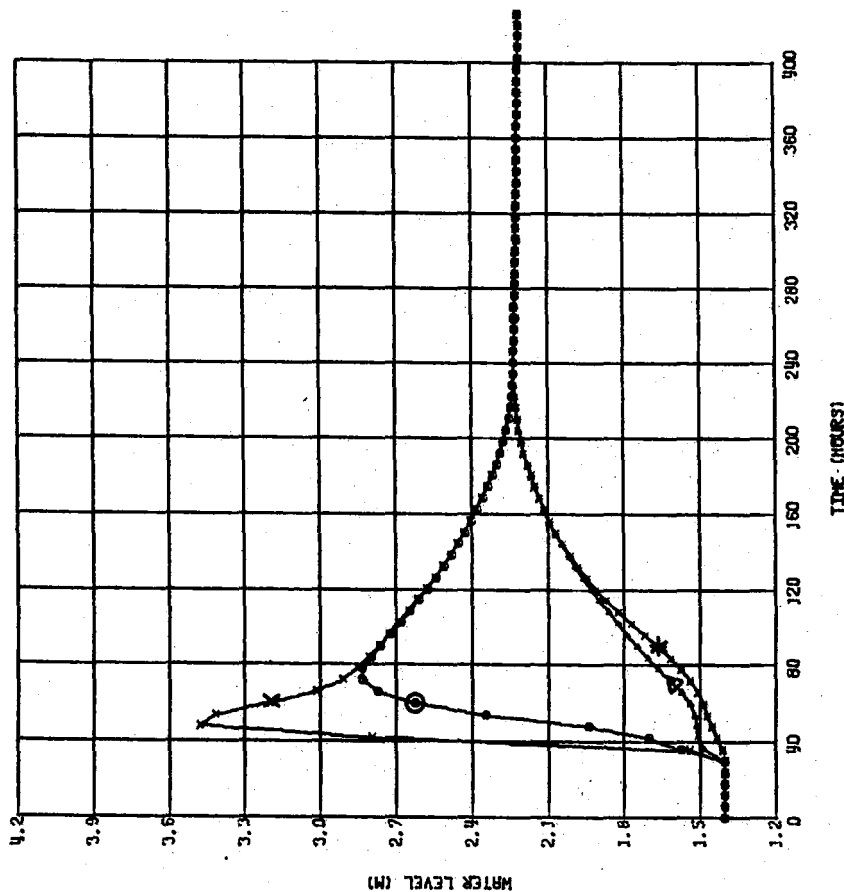
FLOOD : JULY 1979. INITIAL LEVEL : 1.55 M.



TRACED : COMPILOT
CHECKED :
DATE : 1980-08-30
REF. : C/SEA 8113

WILDERNESS NUMERICAL STUDY
MODEL CALIBRATION.
PROTOTYPE DATA - JULY 1979.

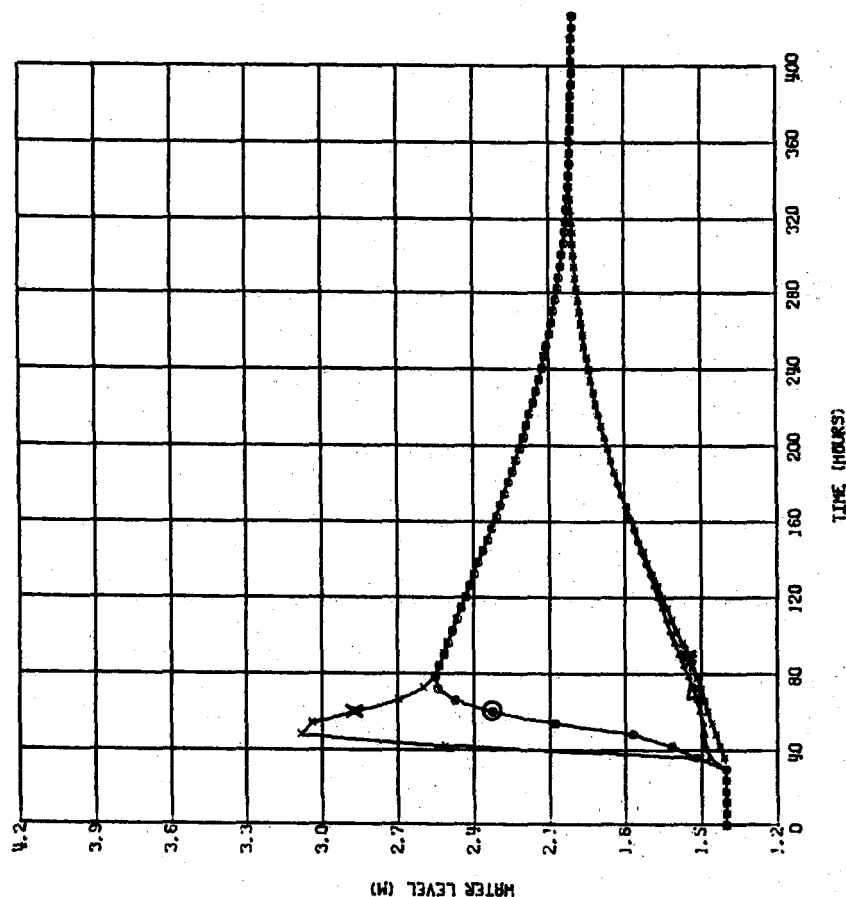
FIGURE
10b



MODEL RESULTS.

ORIGINAL LAYOUT, INITIAL LEVEL : 1.4 M TO MSL.

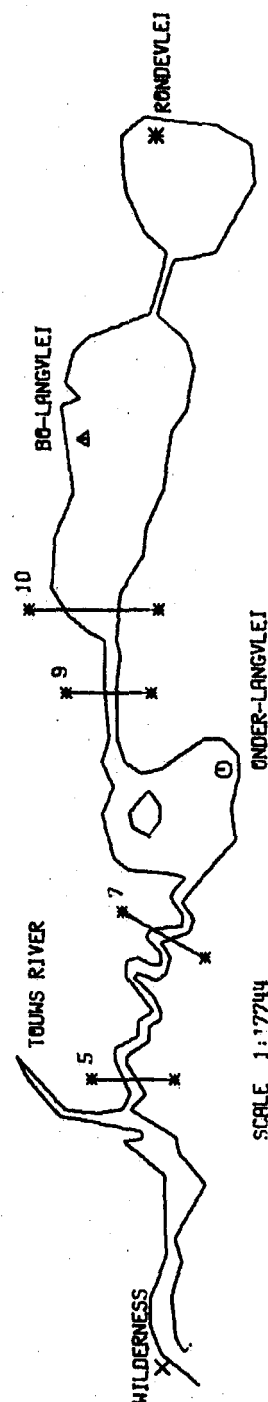
FLOOD : 1 IN 10 YEAR. MAX DISCHARGE: 145.7 M³/S



MODEL RESULTS.

ORIGINAL LAYOUT, INITIAL LEVEL : 1.4 M TO MSL.

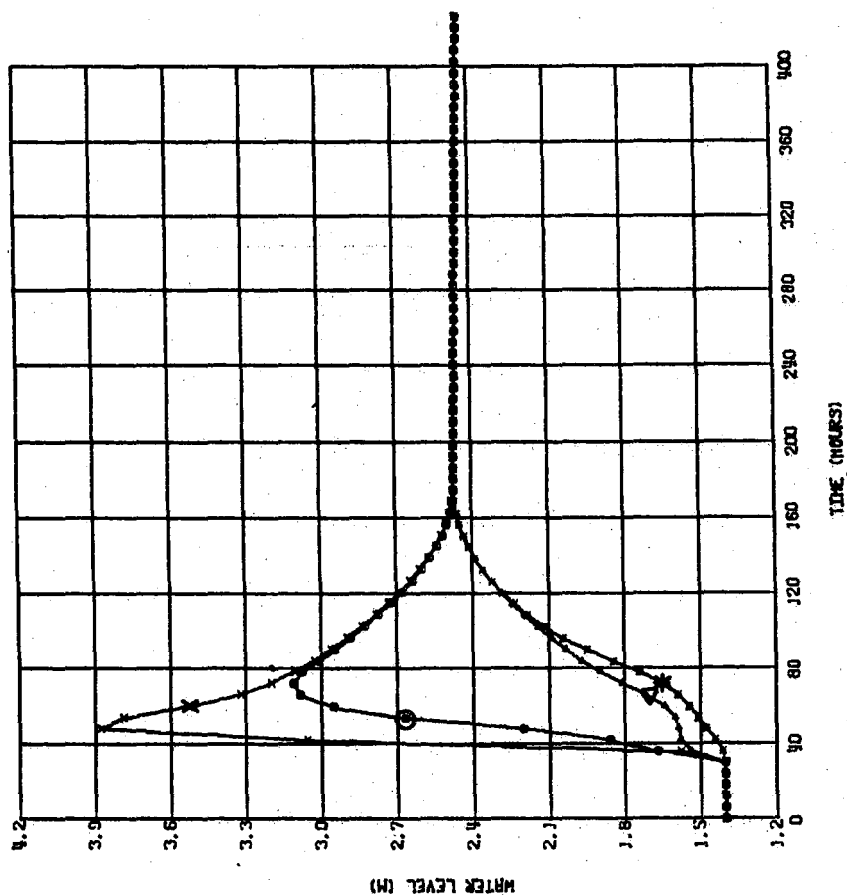
FLOOD : 1 IN 5 YEAR. MAX DISCHARGE: 109.1 M³/S



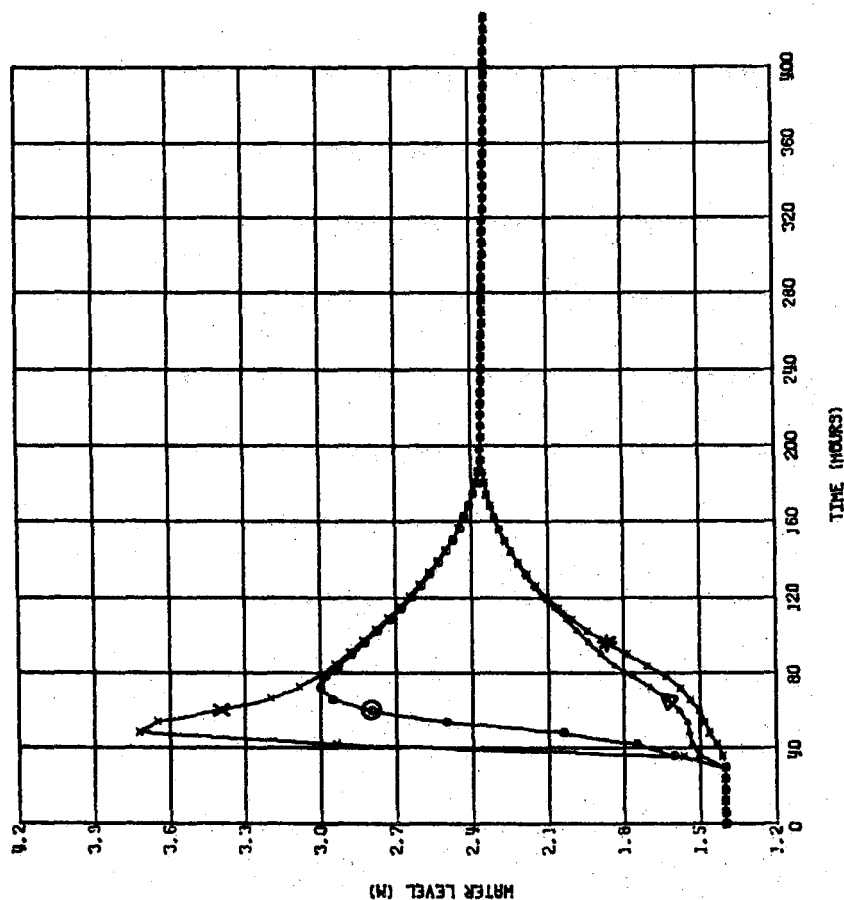
TRACED : COMPILOT
CHECKED :
DATE : 1980-08-30
REF. : C/SEA 8113

WILDERNESS NUMERICAL STUDY
MODEL RESULTS. ORIGINAL LAYOUT.
FLOOD: 1 IN 5 AND 1 IN 10 YEAR.

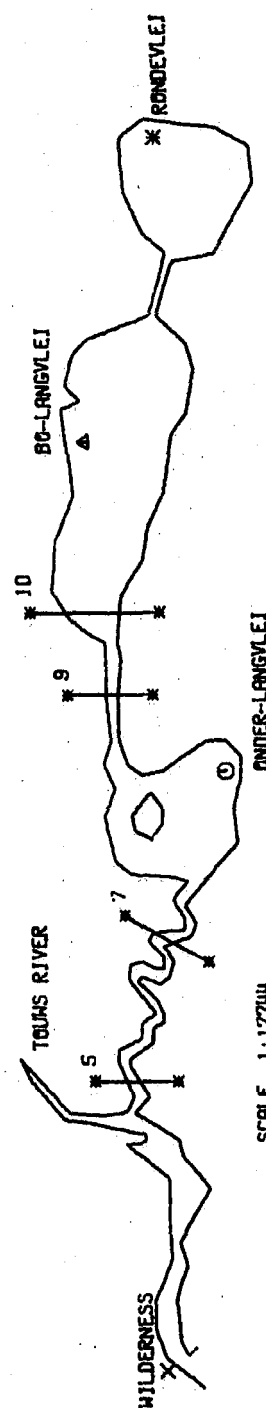
FIGURE
11.1a



MODEL RESULTS.
ORIGINAL LAYOUT. INITIAL LEVEL : 1.4 M TO MSL.
FLOOD : 1 IN 50 YEAR. MAX DISCHARGE: 183.1 M³/S



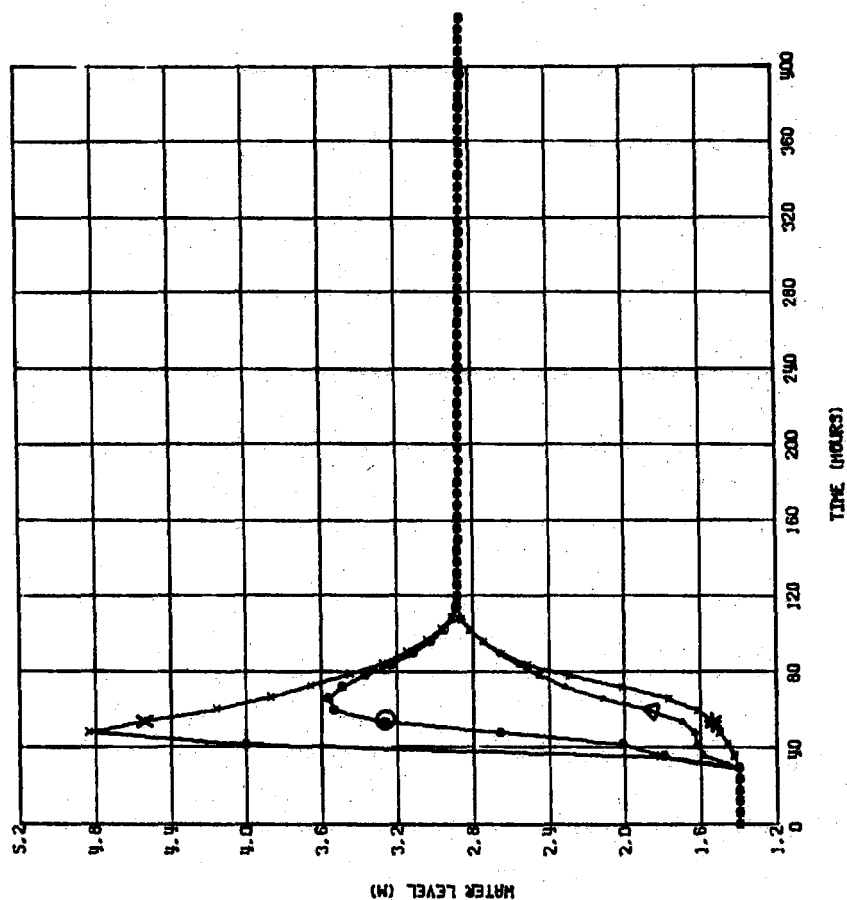
MODEL RESULTS.
ORIGINAL LAYOUT. INITIAL LEVEL : 1.4 M TO MSL.
FLOOD : 1 IN 20 YEAR. MAX DISCHARGE: 170.4 M³/S



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DATE : 1980-08-30
REF. : c/SEA 8113

WILDERNESS NUMERICAL STUDY
MODEL RESULTS. ORIGINAL LAYOUT.
FLOOD: 1 IN 20 AND 1 IN 50 YEAR.

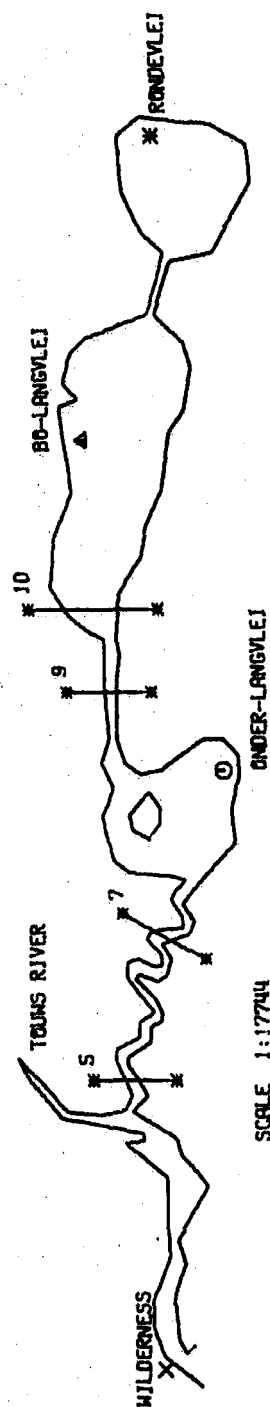
FIGURE
11.1b



MODEL RESULTS.

ORIGINAL LAYOUT. INITIAL LEVEL : 1.4 M TO MSL.

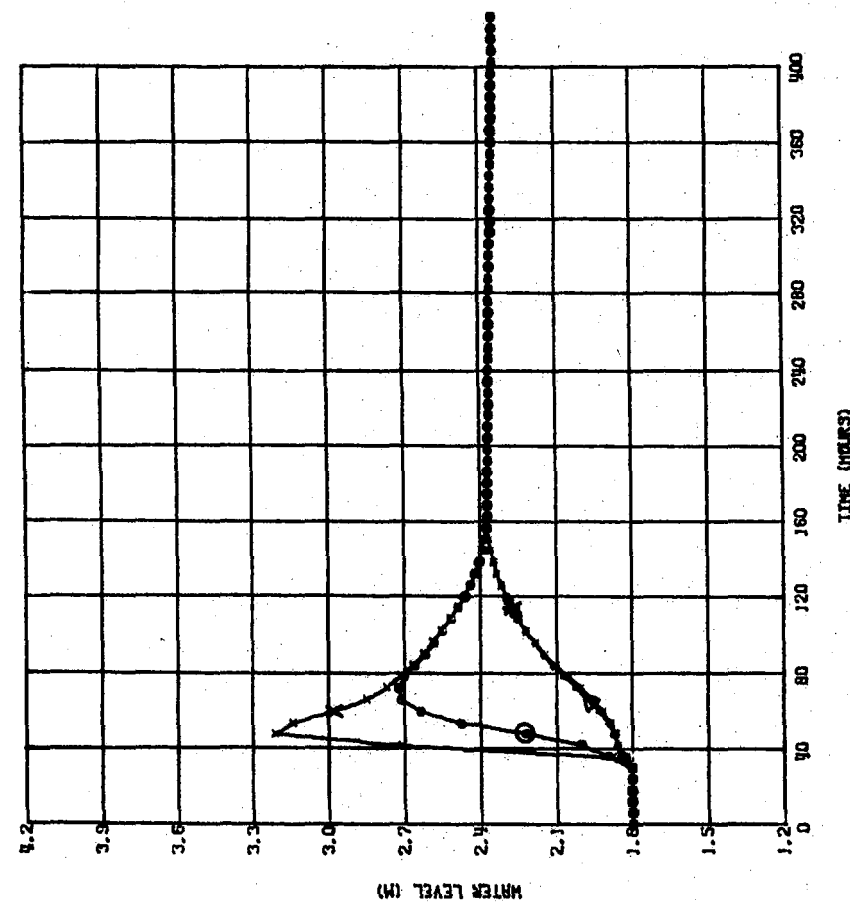
FLOOD : 1 IN 100 YEAR. MAX. DISCHARGE: 276.3 M³/S.



TRACED : COMPLIT
CHECKED :
DATE : 1980-08-30
REF. : C/SEA 8113

WILDERNESS NUMERICAL STUDY
MODEL RESULTS. ORIGINAL LAYOUT.
FLOOD: 1 IN 100 YEAR.

FIGURE
II.1c



TRACED : COMPILOT
CHECKED :
DATE : 1980-08-30
REF. : C/SEA 8113

WILDERNESS NUMERICAL STUDY
MODEL RESULTS. ORIGINAL LAYOUT.
FLOOD: 1 IN 5 AND 1 IN 10 YEAR.

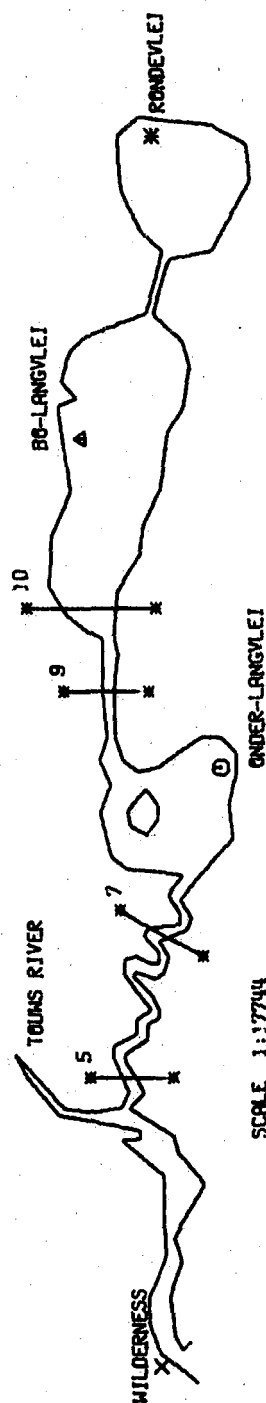
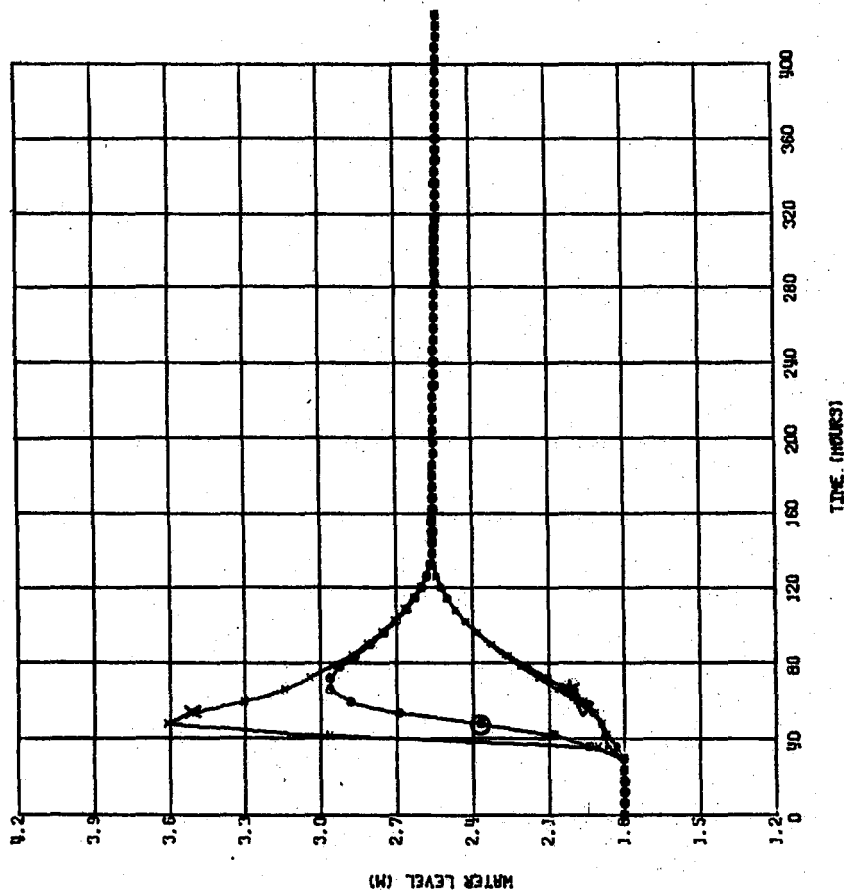
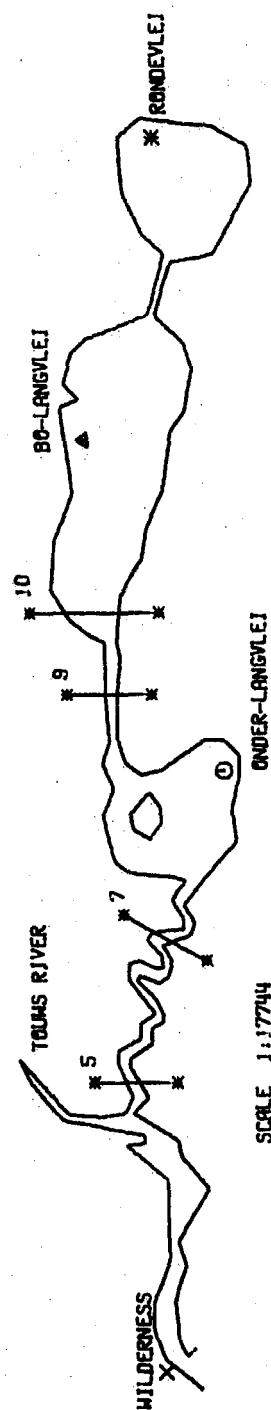
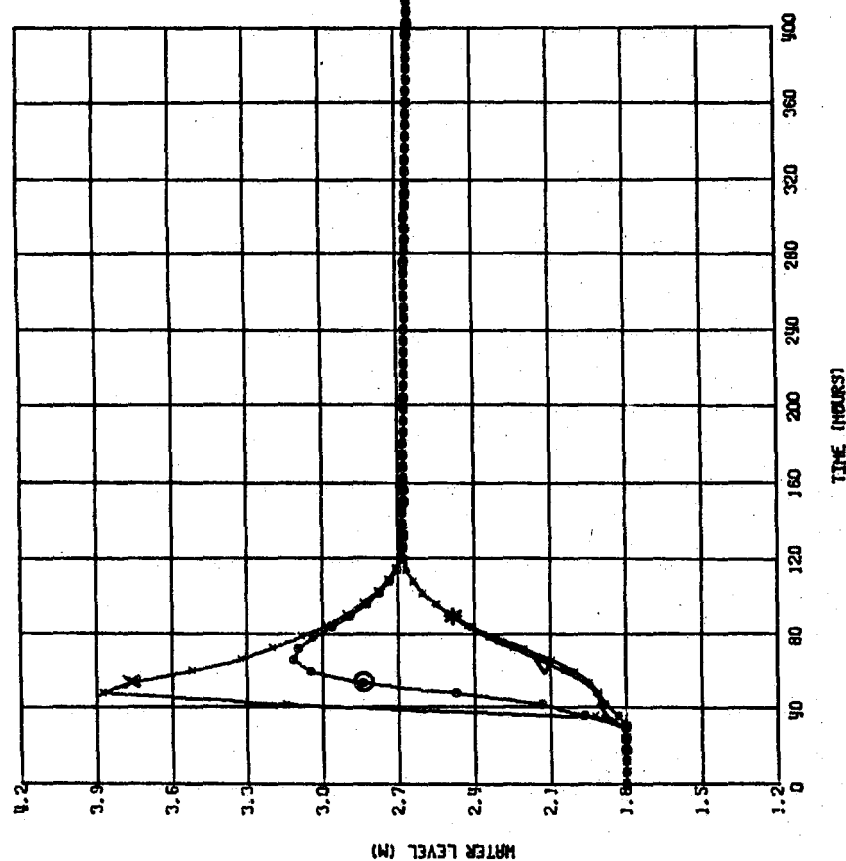
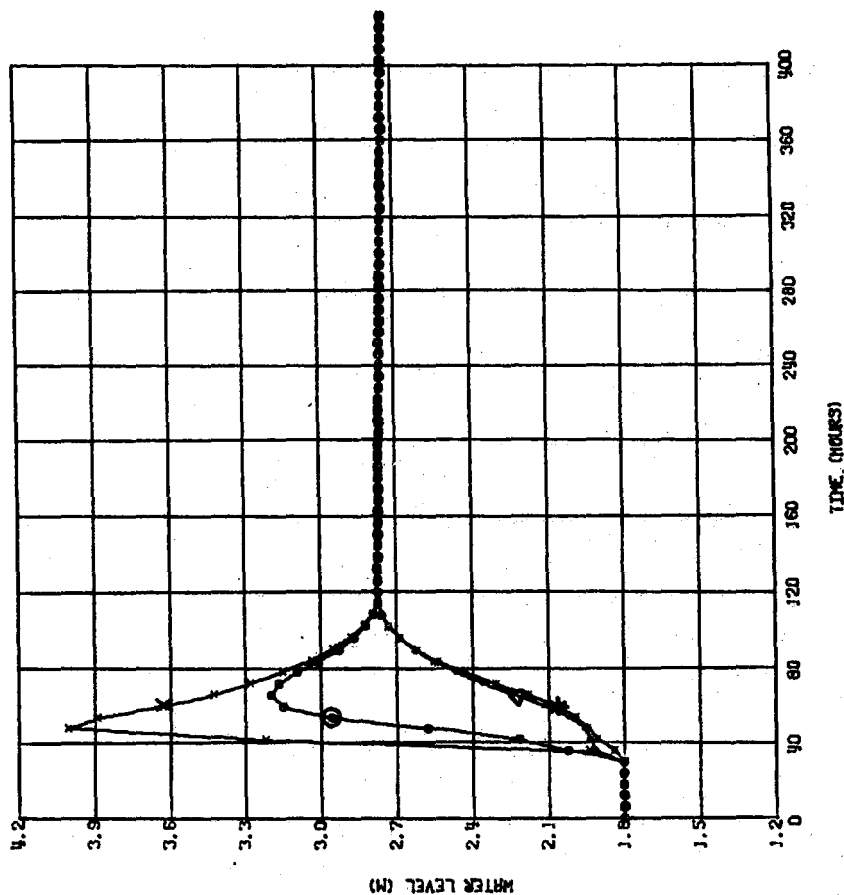


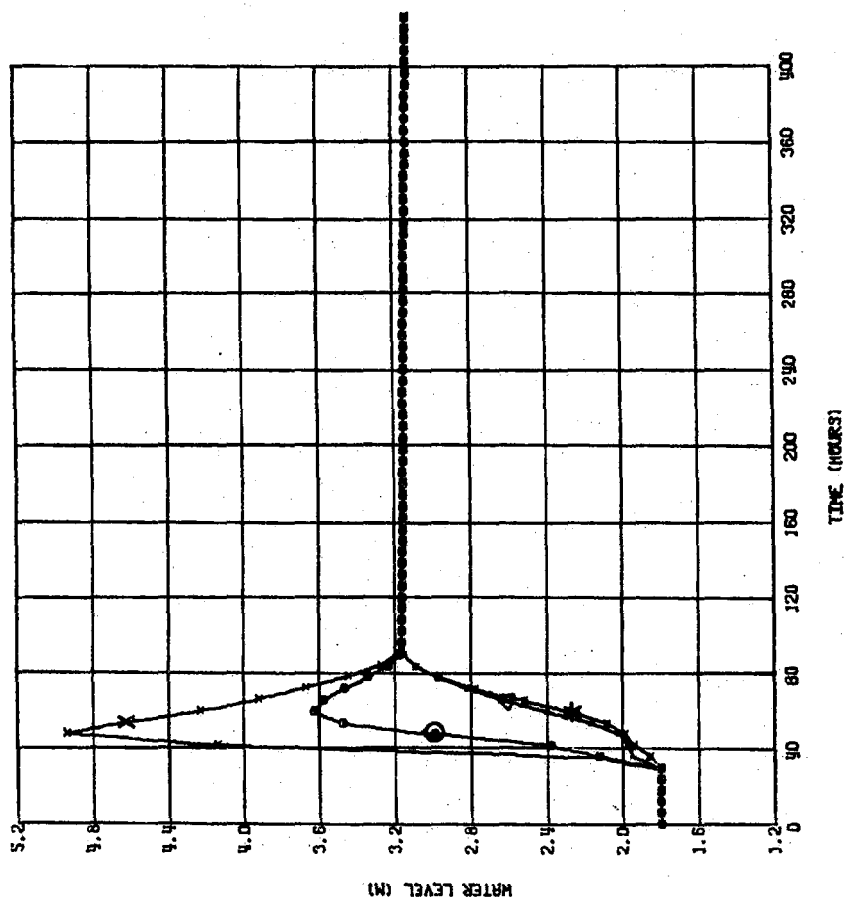
FIGURE
II.2a



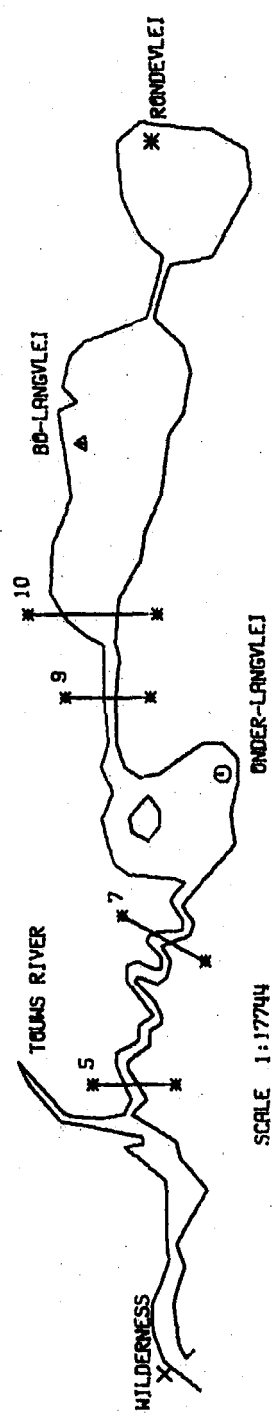
TRACED : COMPLIT
CHECKED :
DATE : 1980-08-30
REF. : C/SEA 8113

WILDERNESS NUMERICAL STUDY
MODEL RESULTS. ORIGINAL LAYOUT.
FLOOD: 1 IN 20 AND 1 IN 50 YEAR.

FIGURE
11.2b



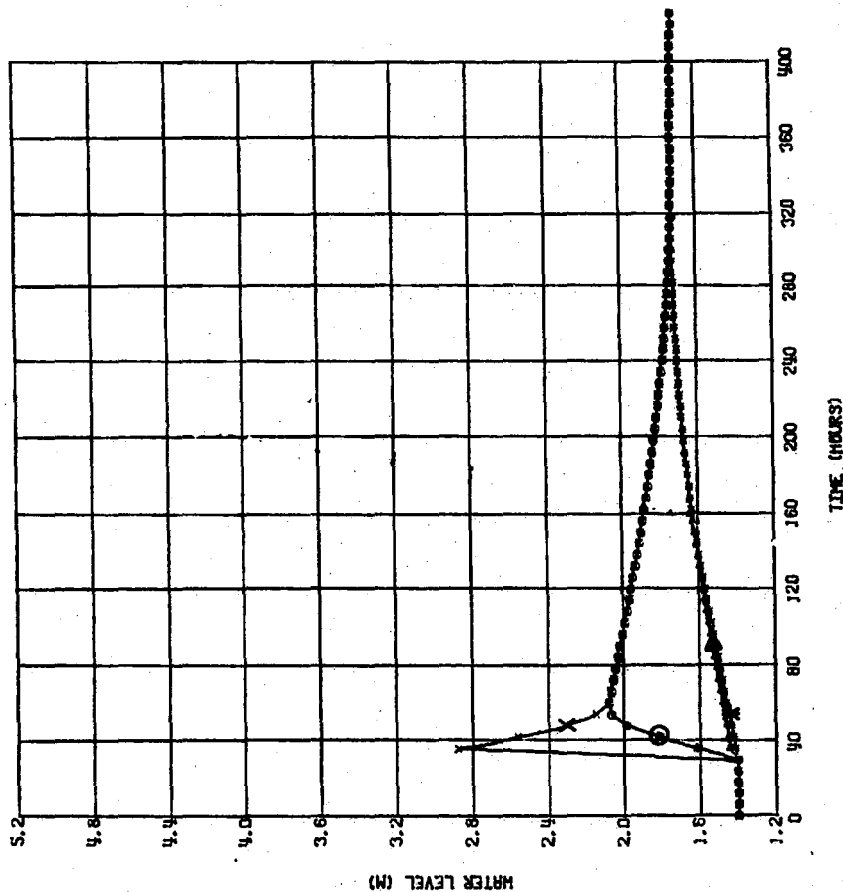
MODEL RESULTS.
 ORIGINAL LAYOUT. INITIAL LEVEL : 1.8 M TO MSL.
 FLOOD : 1 IN 100 YEAR. MAX. DISCHARGE: 278.3 M³/S.



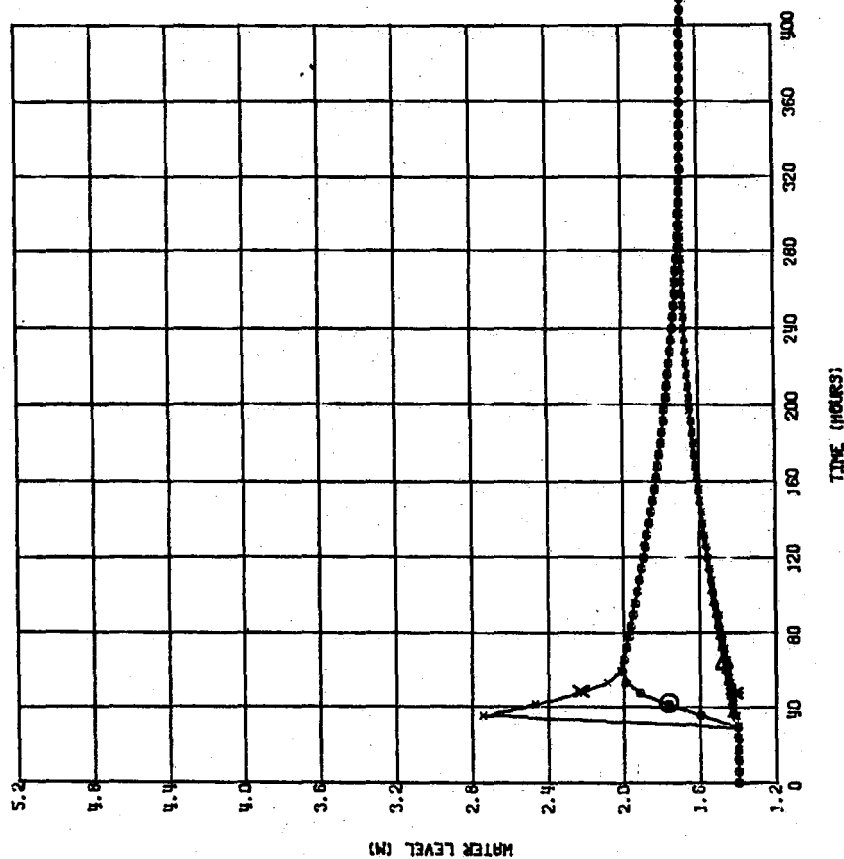
TRACED : COMPLIT
 CHECKED :
 DATE : 1980-08-30
 REF. : C/SEM 8113

WILDERNESS NUMERICAL STUDY
 MODEL RESULTS. ORIGINAL LAYOUT.
 FLOOD: 1 IN 100 YEAR.

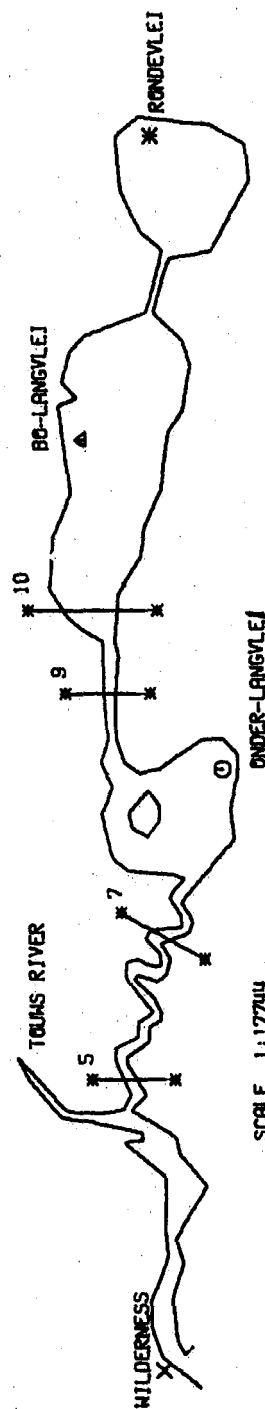
FIGURE
 11.2c



ORIGINAL LAYOUT, INITIAL LEVEL: 1.4 M TO MSL.
FLOOD: 1 IN 100 YEAR. MAX. DISCHARGE: 225.2 M³/S.
TOTAL RUN-OFF TIME: 12.0 HOURS.



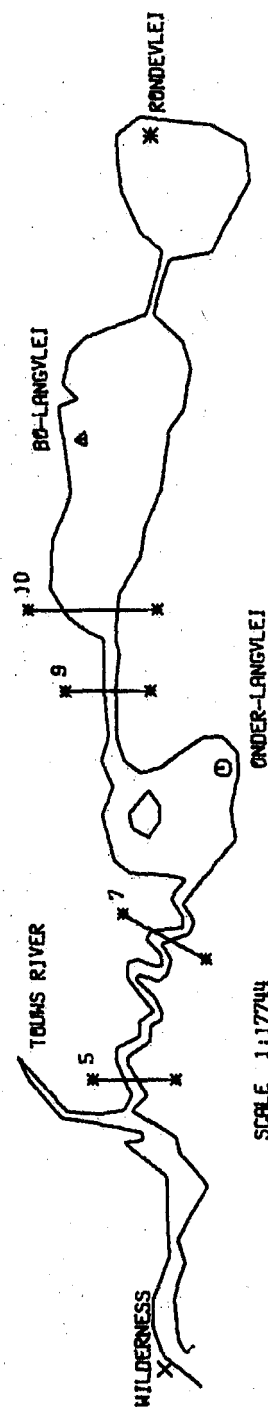
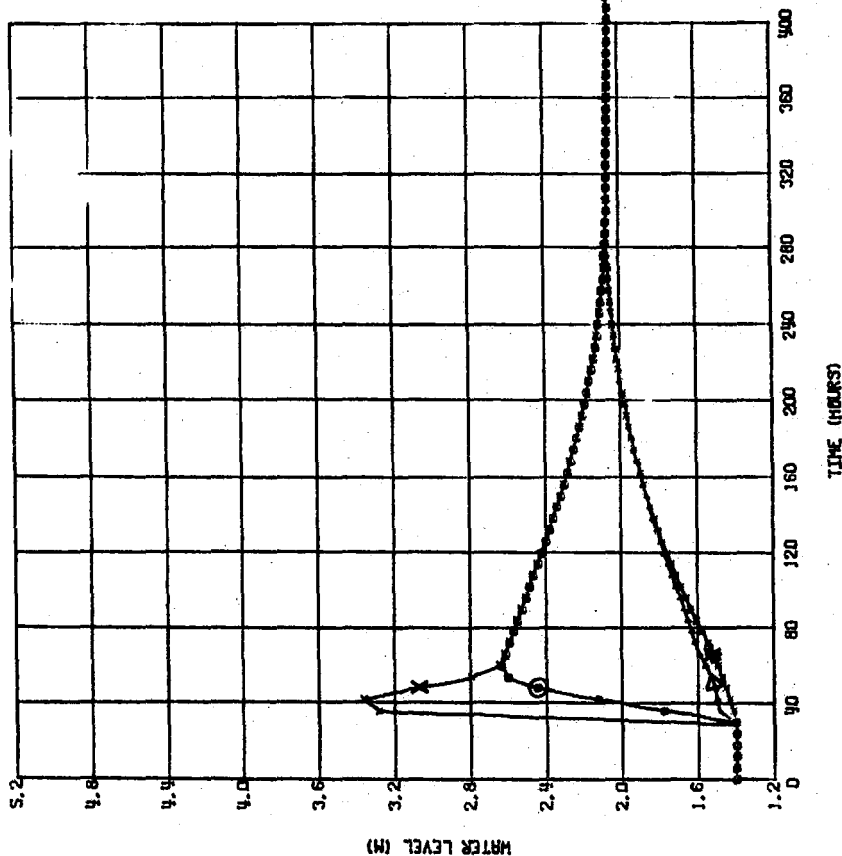
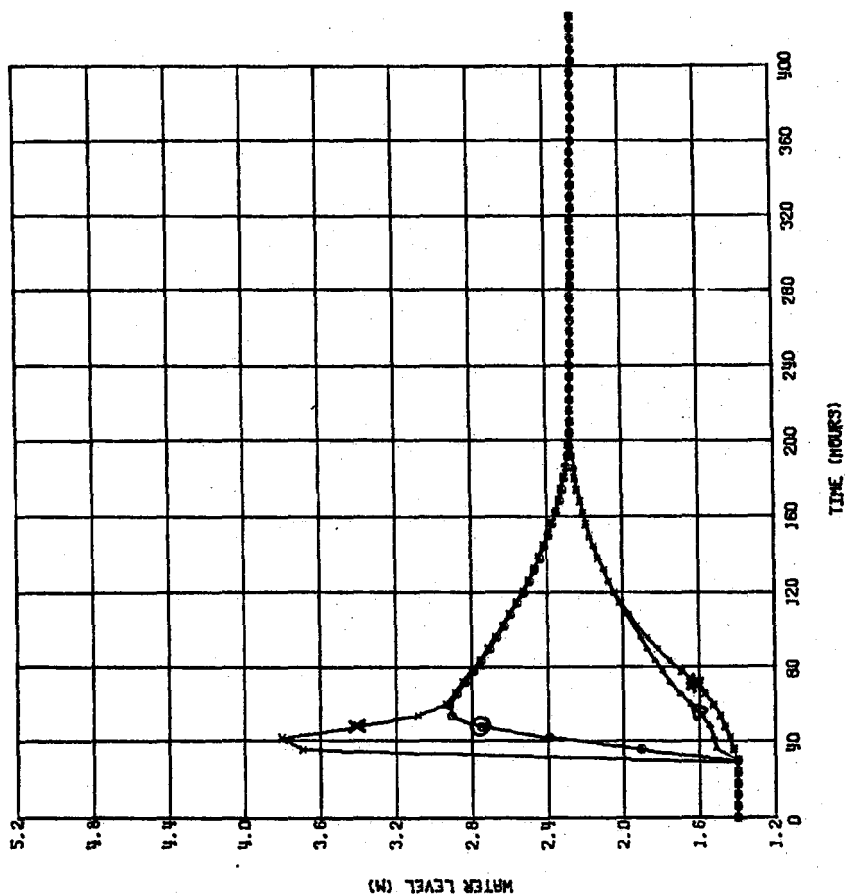
ORIGINAL LAYOUT, INITIAL LEVEL: 1.4 M. TO MSL.
FLOOD: 1 IN 50 YEAR. MAXIMUM DISCHARGE: 166.8 M³/S
TOTAL RUN-OFF TIME: 13.5 HOURS.



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REF. : C/SEA 8113

WILDERNESS NUMERICAL STUDY
MODEL RESULTS. RUNHYDROGRAPHS (NO.1)
FLOOD: 1 IN 50 AND 1 IN 100 YEAR.

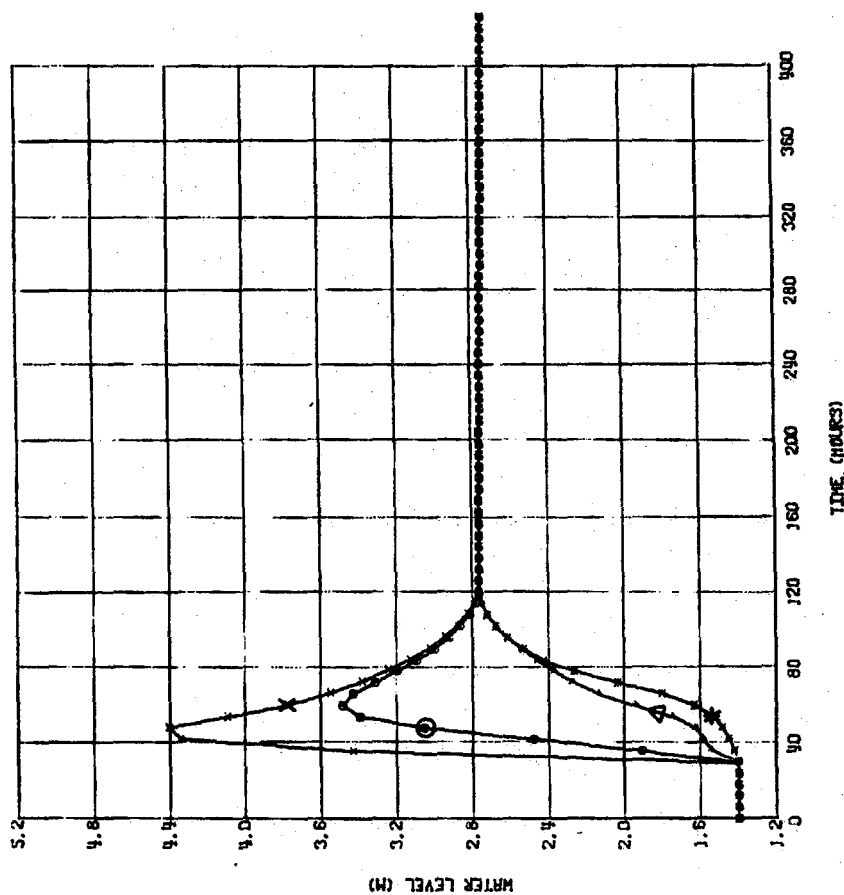
FIGURE
120



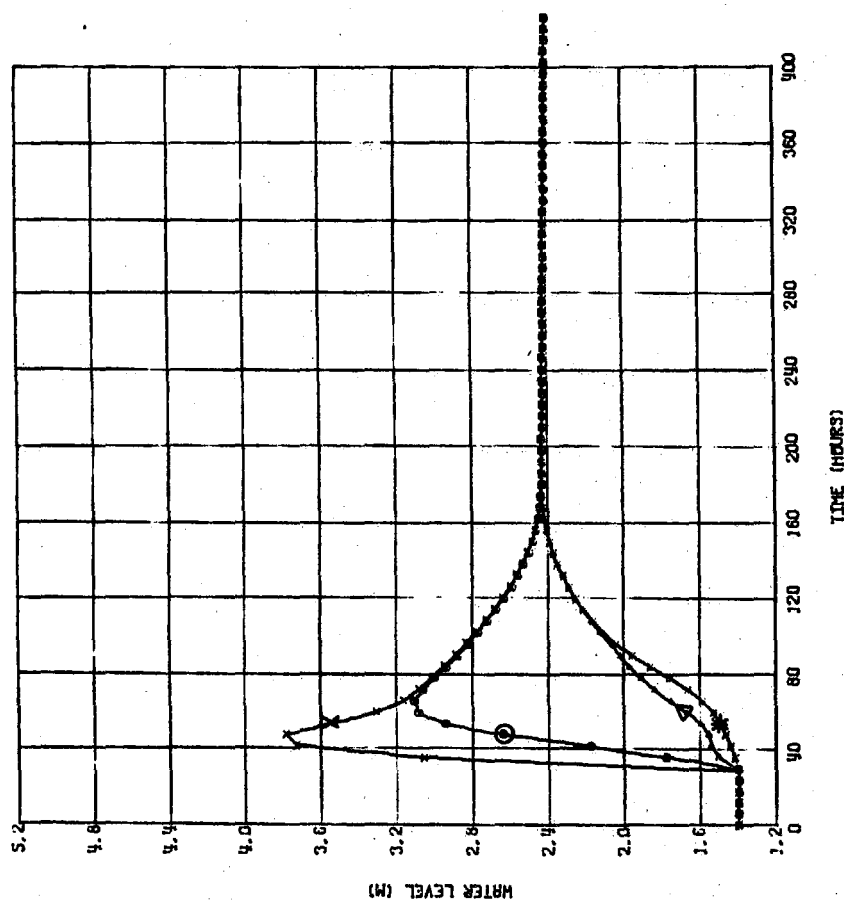
TRACED : COMPILOT
CHECKED :
DATE : 1980-08-30
REF. : C/SEA 8113

WILDERNESS NUMERICAL STUDY
MODEL RESULTS. RUNHYDROGRAPHS (NO.2)
FLOOD: 1 IN 50 AND 1 IN 100 YEAR.

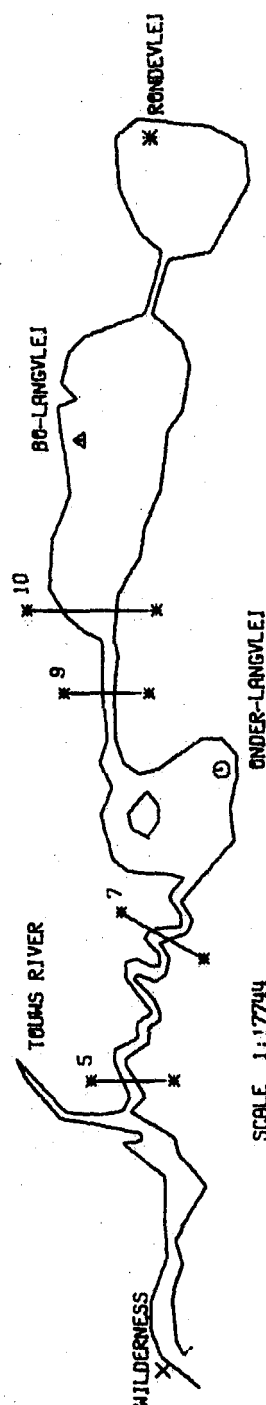
FIGURE
12 b



ORIGINAL LAYOUT. INITIAL LEVEL: 1.4 M TO MSL.
 FLOOD: 1 IN 100 YEAR. MAX. DISCHARGE: 177.0 M³/S.
 TOTAL RUN-OFF TIME: 53.0 HOURS.



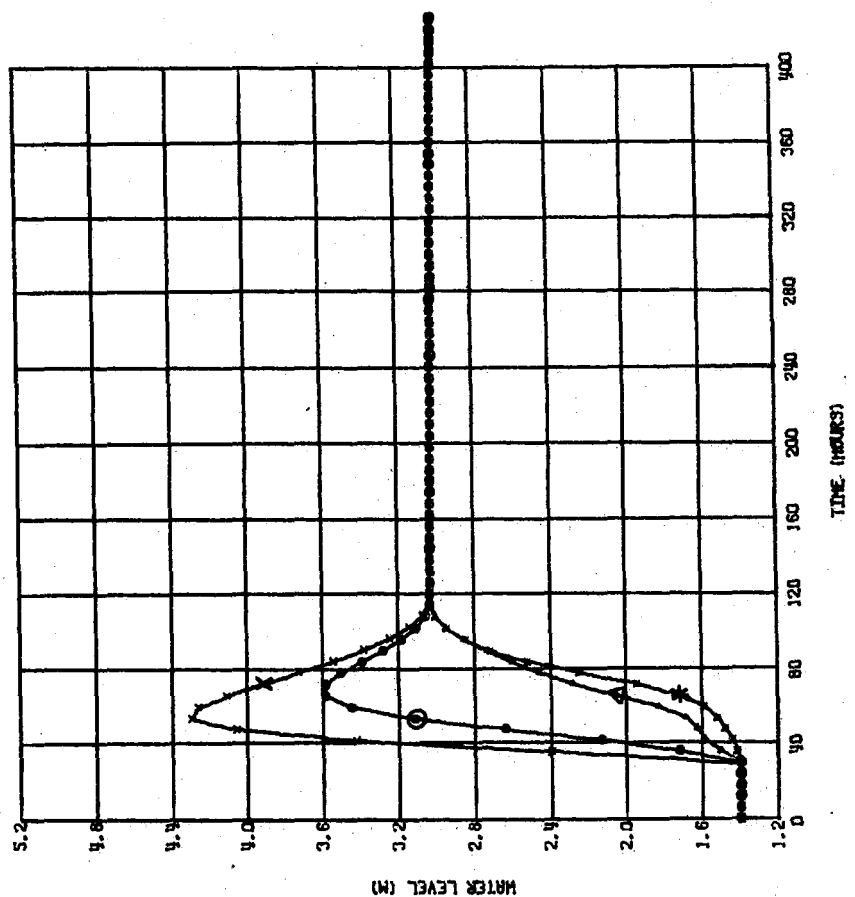
ORIGINAL LAYOUT. INITIAL LEVEL: 1.4 M. TO MSL.
 FLOOD: 1 IN 50 YEAR. MAXIMUM DISCHARGE: 130.9 M³/S
 TOTAL RUN-OFF TIME: 50.0 HOURS.



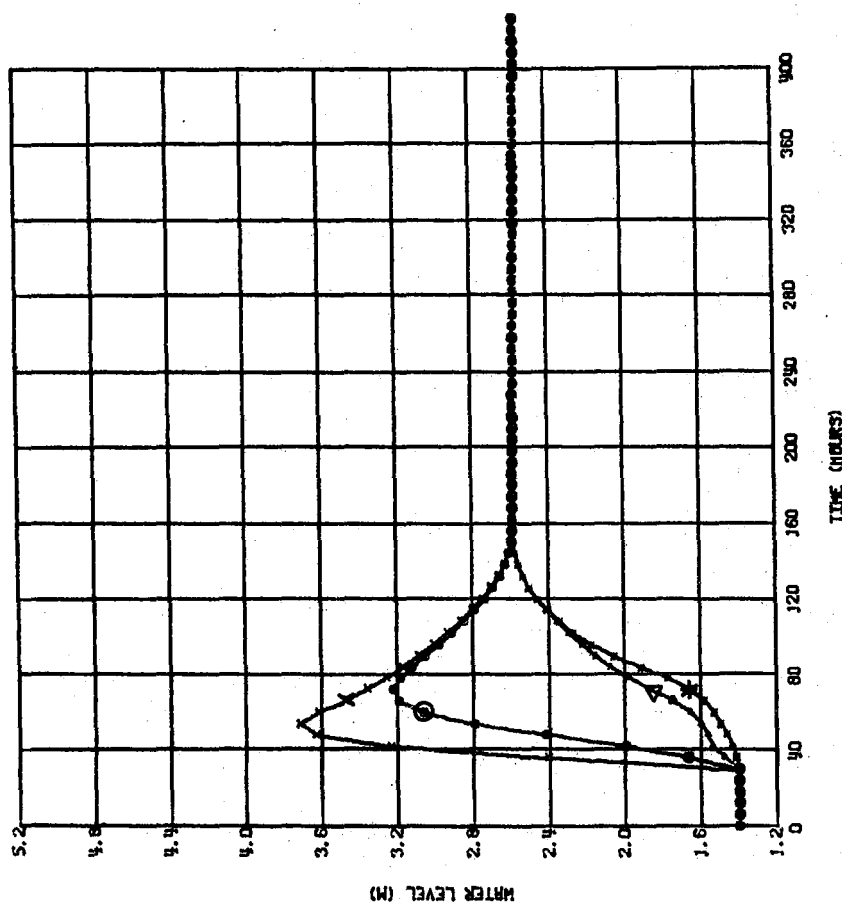
TRACED : COMPLIT
 CHECKED :
 DATE : 1980-08-30
 REF. : C/SEA 8113

WILDERNESS NUMERICAL STUDY
 MODEL RESULTS. RUNHYDROGRAPHS (NO.3)
 FLOOD: 1 IN 50 AND 1 IN 100 YEAR.

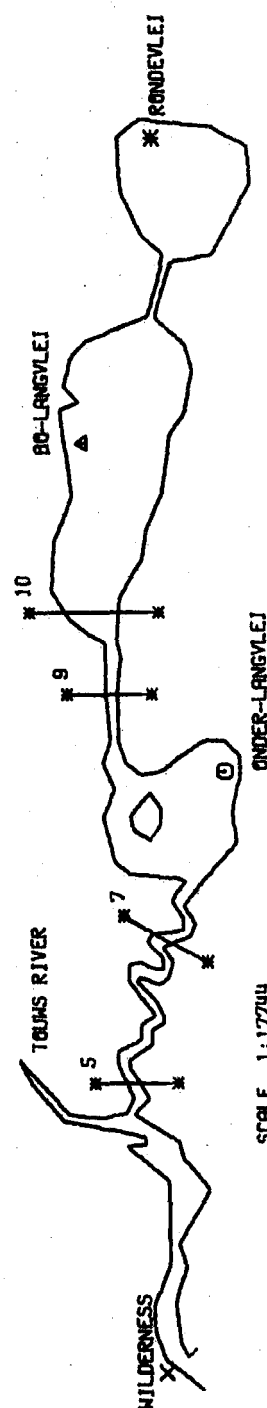
FIGURE
 12c



ORIGINAL LAYOUT. INITIAL LEVEL: 1.4 M TO MSL.
FLOOD: 1 IN 100 YEAR. MAX. DISCHARGE: 119.7 Max3/S.
TOTAL RUN-OFF TIME: 87.0 HOURS.



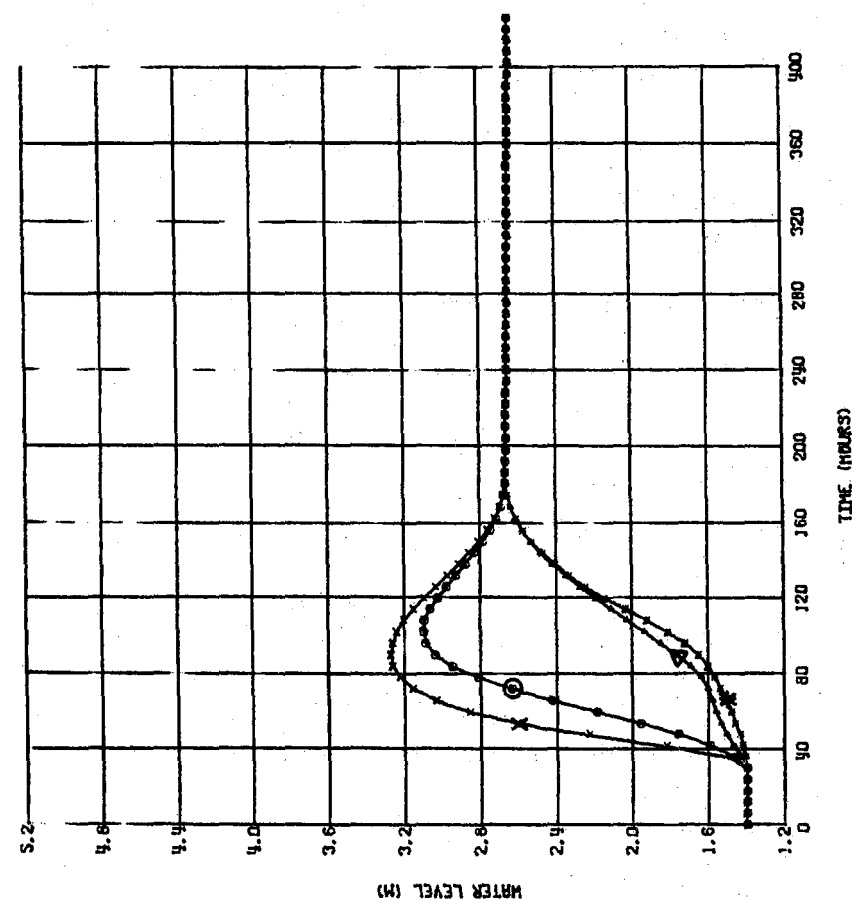
ORIGINAL LAYOUT. INITIAL LEVEL: 1.4 M. TO MSL.
FLOOD: 1 IN 50 YEAR. MAXIMUM DISCHARGE: 95.0 Max3/S
TOTAL RUN-OFF TIME: 74.5 HOURS.



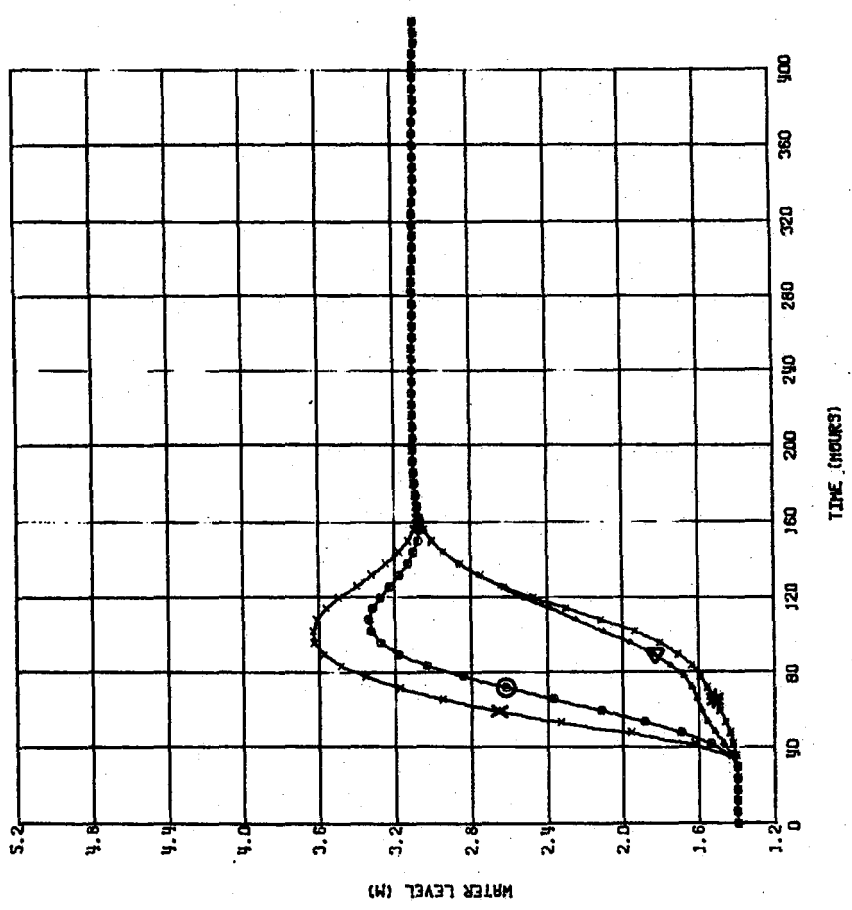
TRACED : COMPILOT
CHECKED :
DATE : 1980-08-30
REF. : C/SEA 8113

WILDERNESS NUMERICAL STUDY
MODEL RESULTS. RUNHYDROGRAPHS (NO.4)
FLOOD: 1 IN 50 AND 1 IN 100 YEAR.

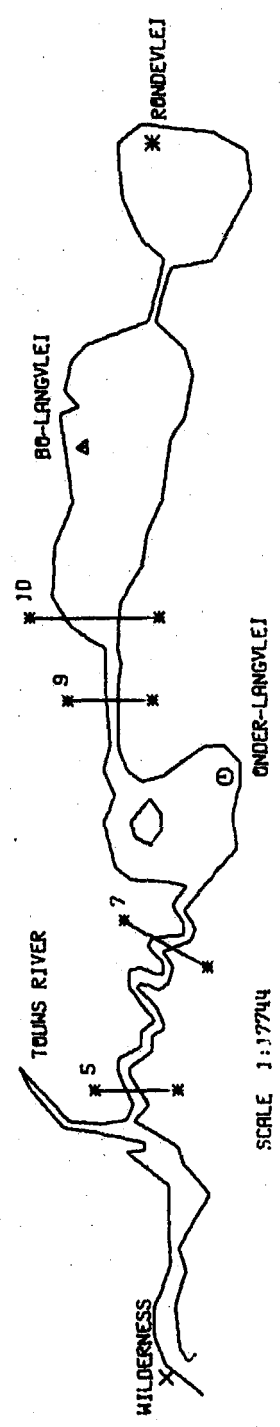
FIGURE
12d



ORIGINAL LAYOUT. INITIAL LEVEL: 1.4 M. TO MSL.
FLOOD: 1 IN 50 YEAR. MAXIMUM DISCHARGE: 45.0 M³/S.
TOTAL RUN-OFF TIME: 146.0 HOURS.



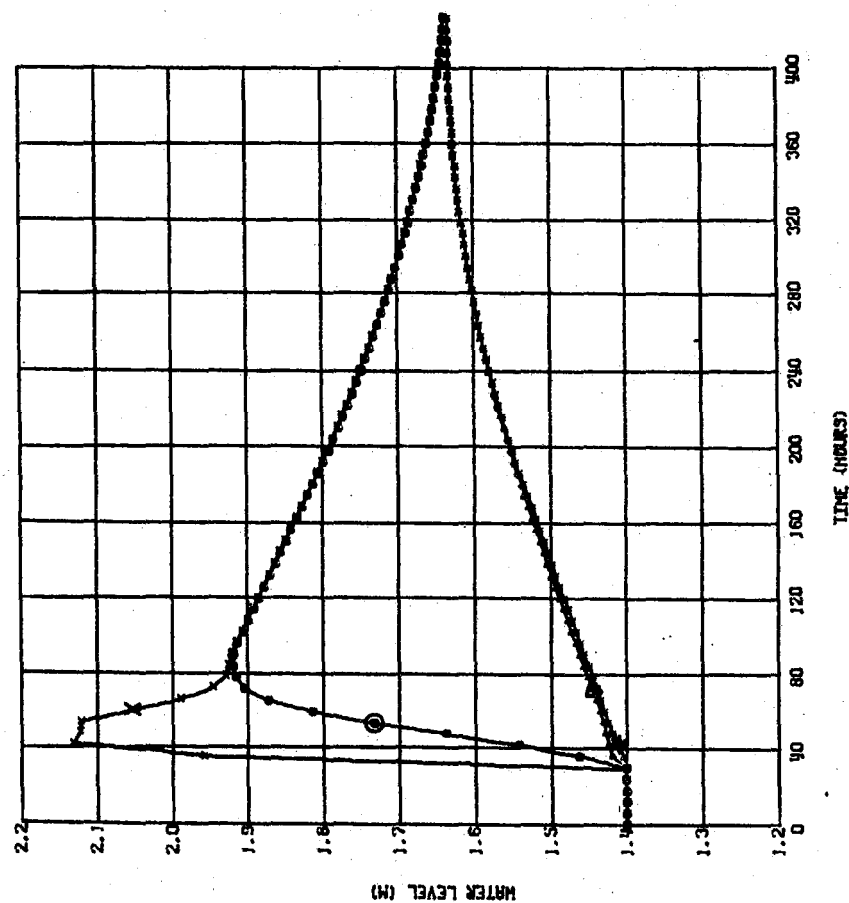
ORIGINAL LAYOUT. INITIAL LEVEL: 1.4 M TO MSL.
FLOOD: 1 IN 100 YEAR. MAX. DISCHARGE: 50.8 M³/S.
TOTAL RUN-OFF TIME: 186.5 HOURS.



TRACED : COMPILOT
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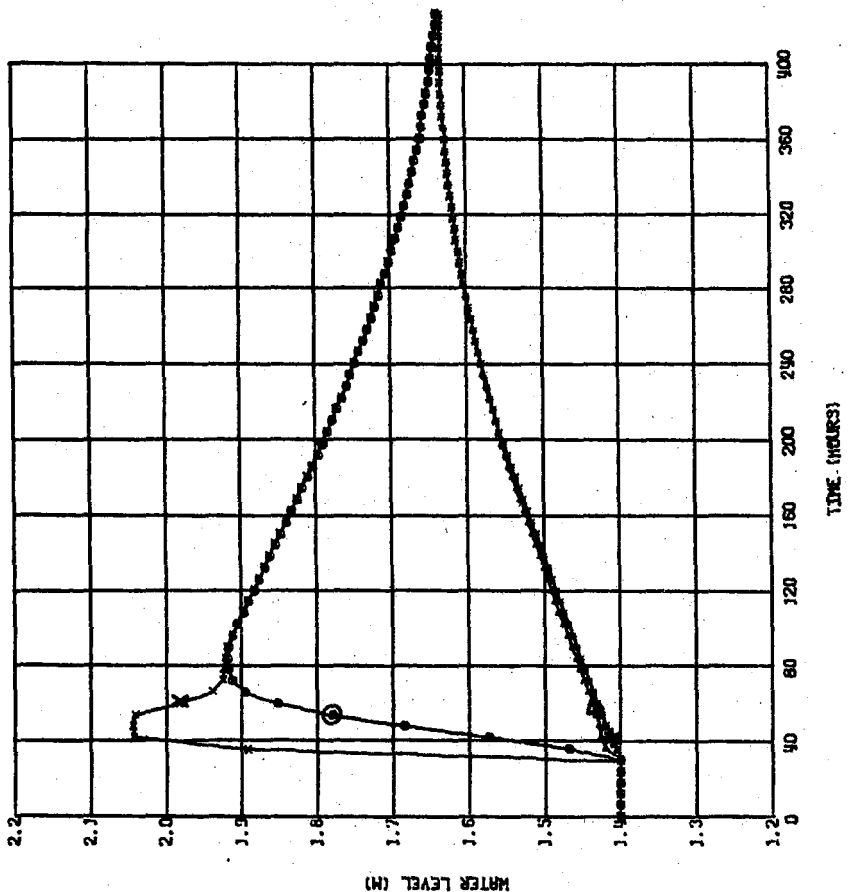
WILDERNESS NUMERICAL STUDY
MODEL RESULTS. RUNHYDROGRAPHS (NO.5)
FLOOD: 1 IN 50 AND 1 IN 100 YEAR.

FIGURE
12 e



MODEL RESULTS.
ORIGINAL LAYOUT.

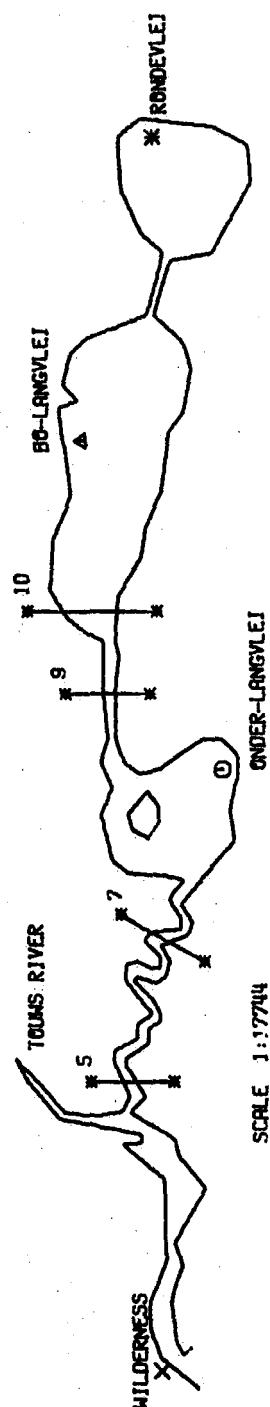
FLOOD : JANUARY 1979. INITIAL LEVEL : 1.40 M.



MODEL RESULTS. SERPENTINE DREDGED TO 0.0 M (MSL)

SECTIONS 5 AND 7.

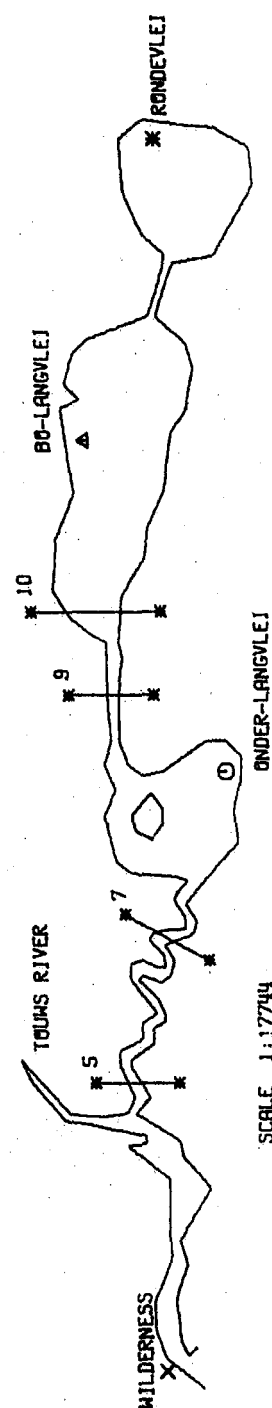
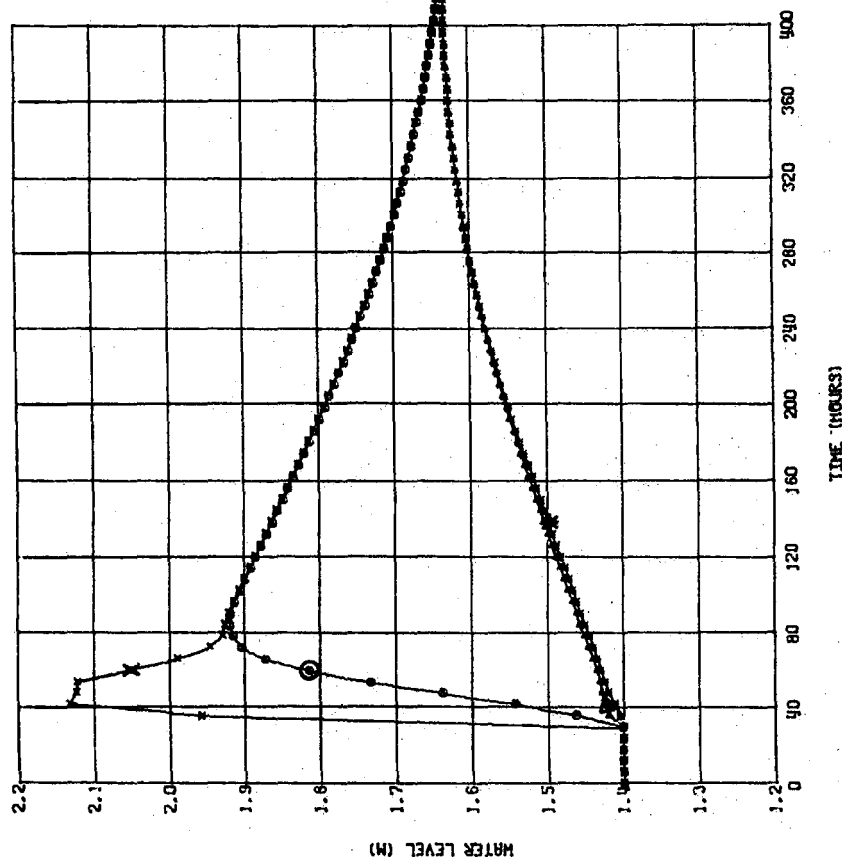
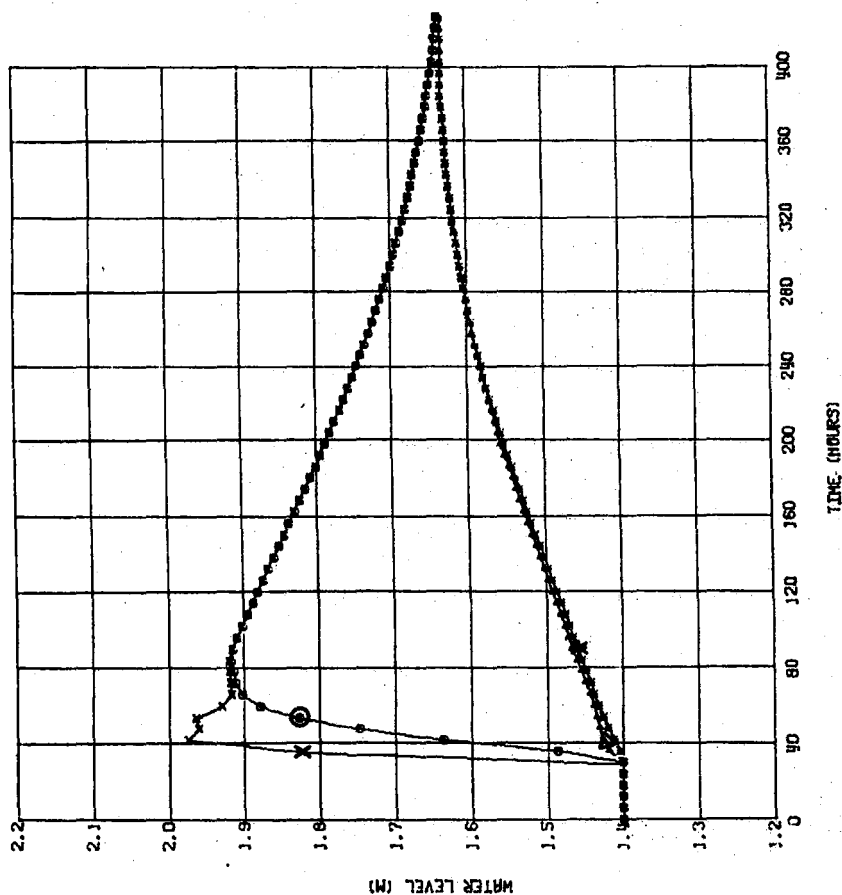
FLOOD : JANUARY 1979. INITIAL LEVEL 1.40 M.



TRACED : COMPILOT
CHECKED :
DATE : 1980-08-30
REF. : C/SEA 8113

WILDERNESS NUMERICAL STUDY
SERPENTINE DREDGED TO 0.0m MSL
PROTOTYPE DATA - JANUARY 1979.

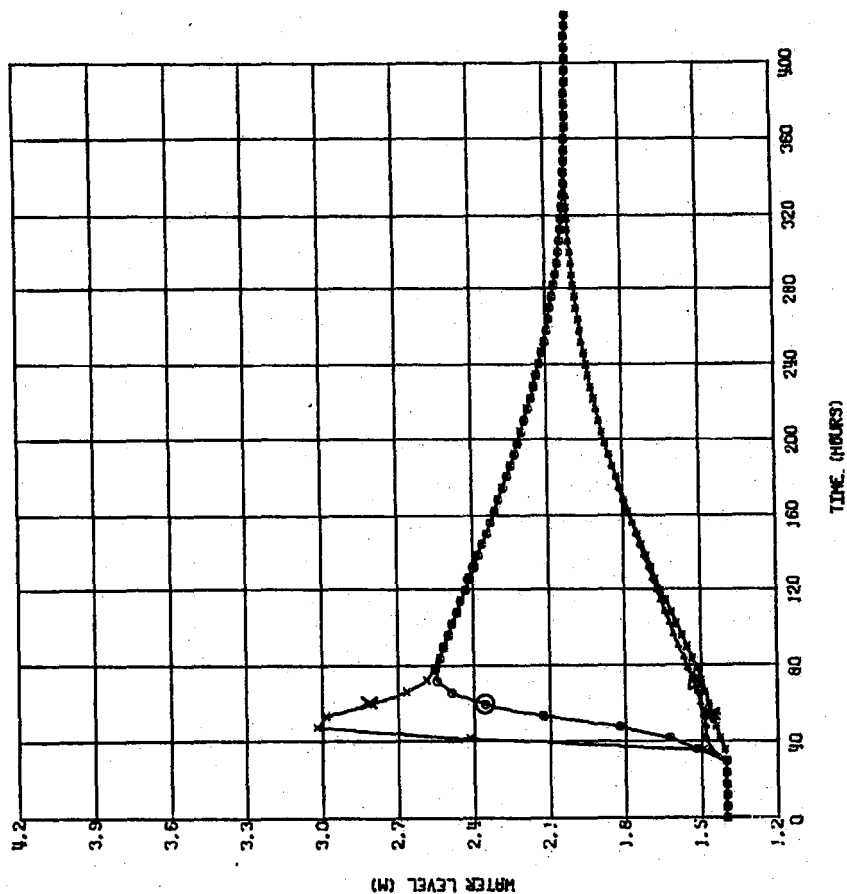
FIGURE
13.1



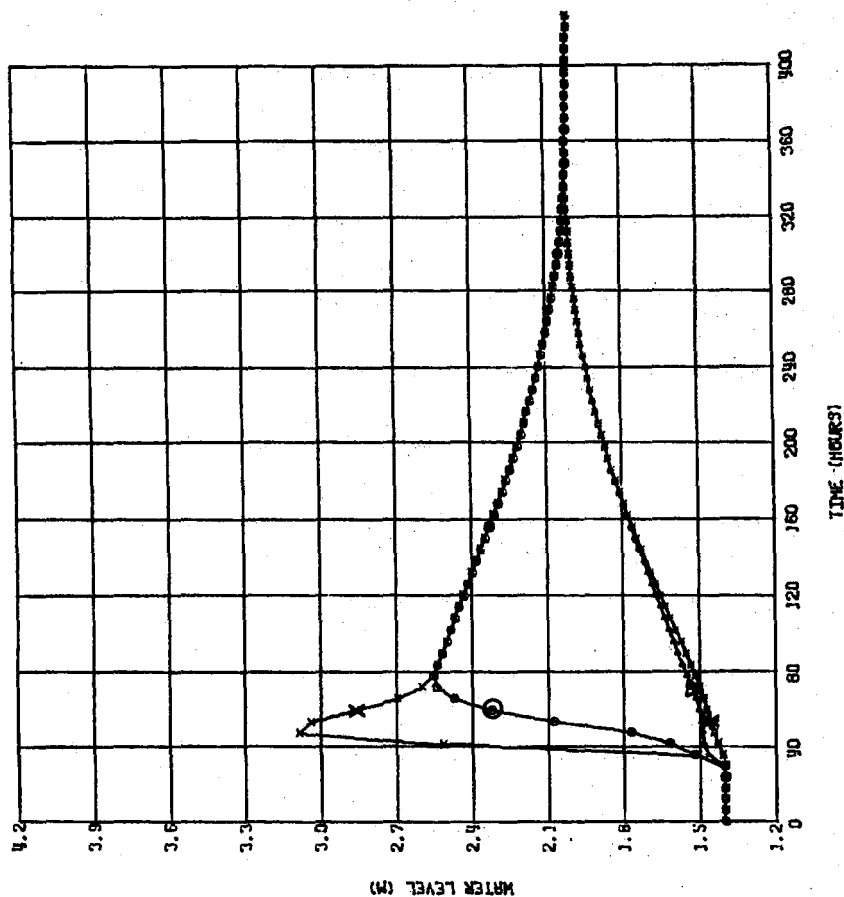
TRACED : COMPLIT
CHECKED :
DATE : 1980-08-30
REF. : C/SEA 8113

WILDERNESS NUMERICAL STUDY
SERPENTINE DREDGED TO -1,0m MSL
PROTOTYPE DATA - JANUARY 1979.

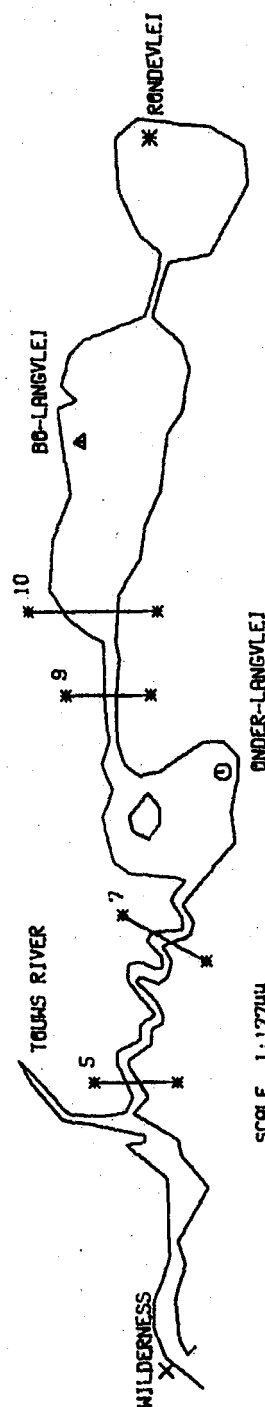
FIGURE
13.2



MODEL RESULTS. SERPENTINE DREDGED TO 0.0 M TO MSL.
 INITIAL LEVEL: 1.4 M.
 FLOOD: 1 IN 5 YEAR. MAX. DISCHARGE: 109.1 M³/S



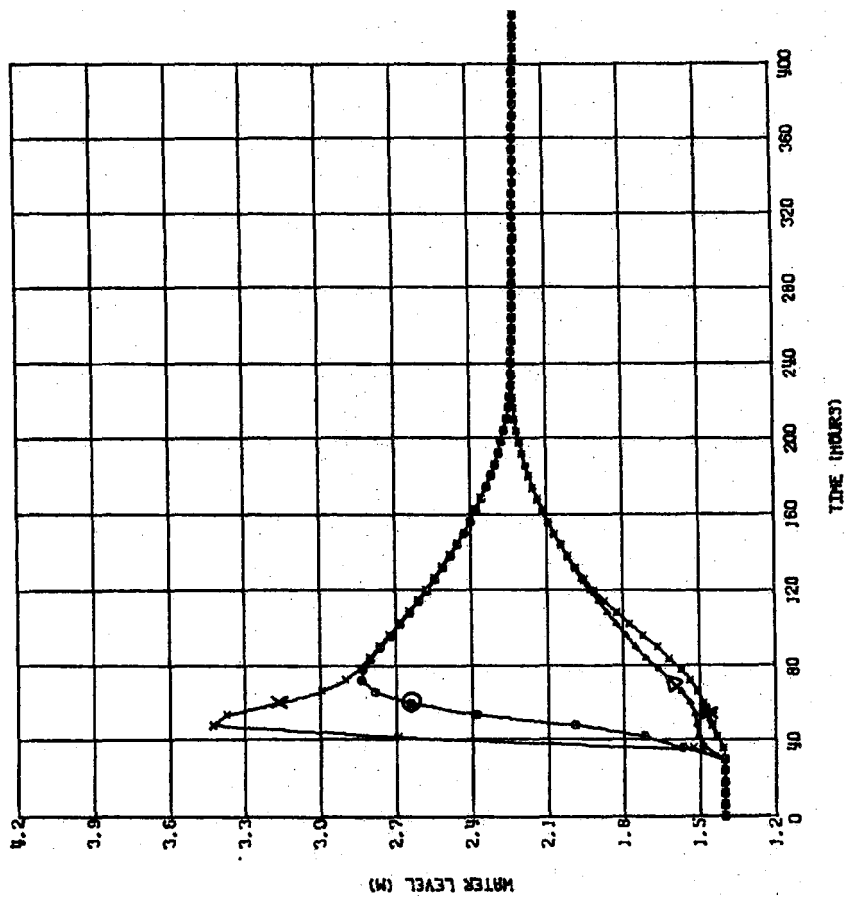
MODEL RESULTS.
 ORIGINAL LAYOUT. INITIAL LEVEL: 1.4 M TO MSL. *
 FLOOD: 1 IN 5 YEAR. MAX. DISCHARGE: 109.1 M³/S.



TRACED : COMPILOT
 CHECKED :
 DATE : 1980-08-30
 REF. : C/SEA 8113

WILDERNESS NUMERICAL STUDY
 SERPENTINE DREDGED TO 0.0 M.
 FLOOD: 1 IN 5 YEAR.

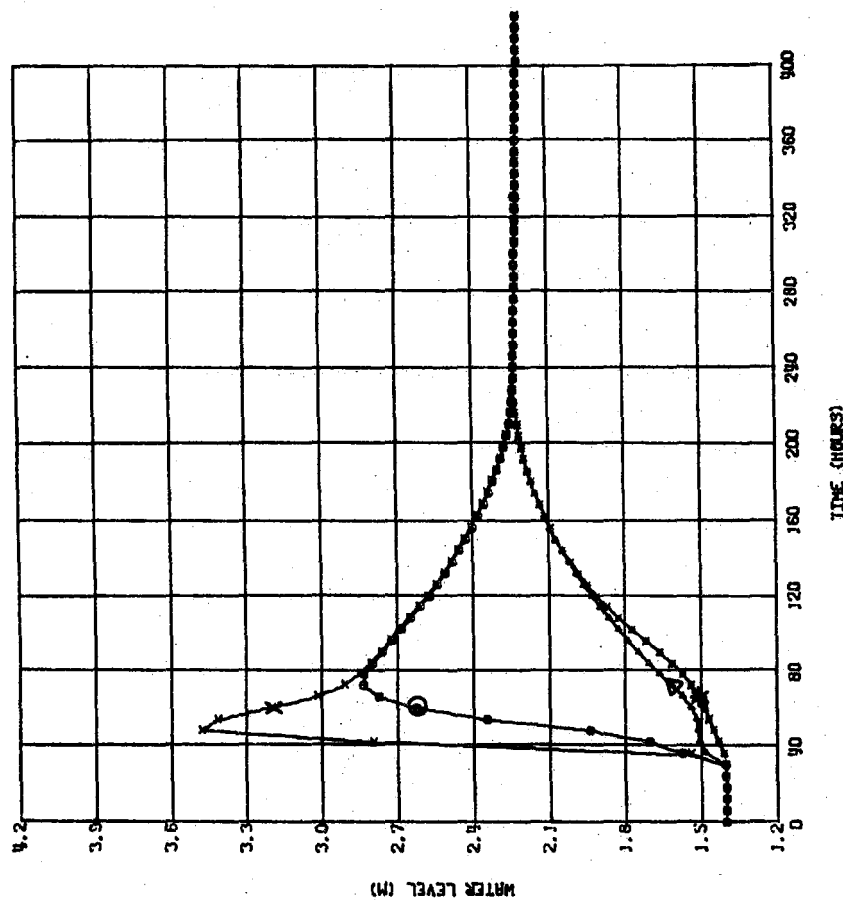
FIGURE
 13.3a



MODEL RESULTS. SERPENTINE DREDGED TO 0.0 M TO MSL.

INITIAL LEVEL: 1.4 M.

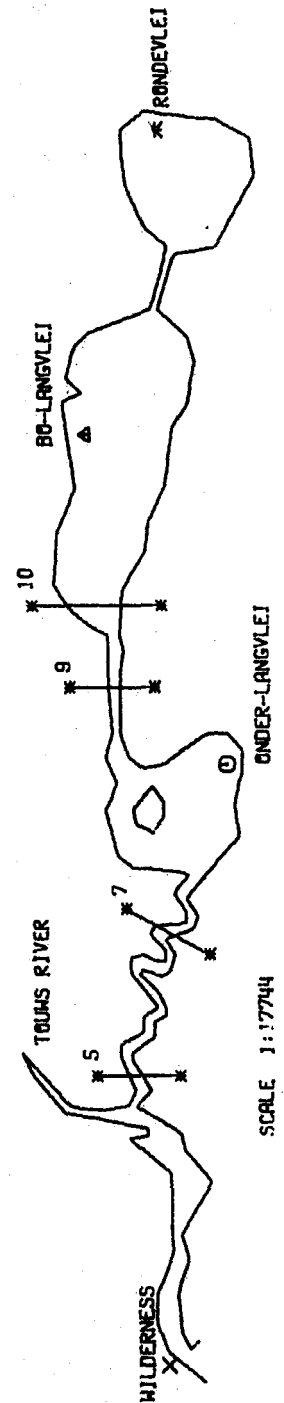
FLOOD: 1 IN 10 YEAR, MAX. DISCHARGE: 145.7 M³/S



MODEL RESULTS.

ORIGINAL LAYOUT. INITIAL LEVEL: 1.4 M. *

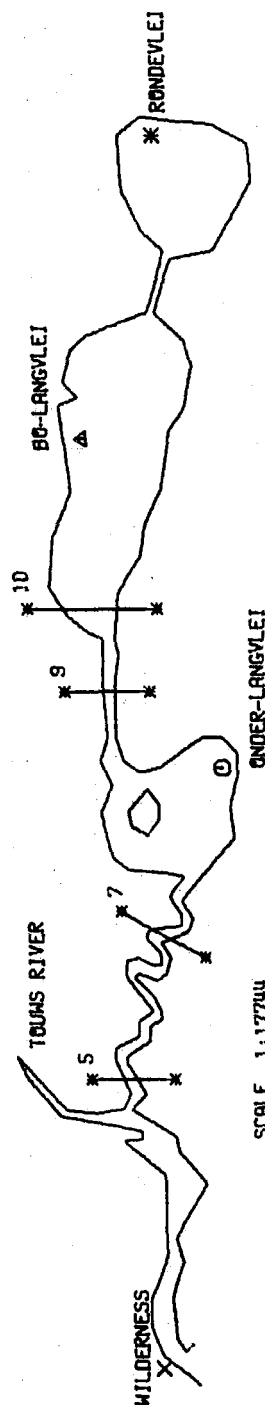
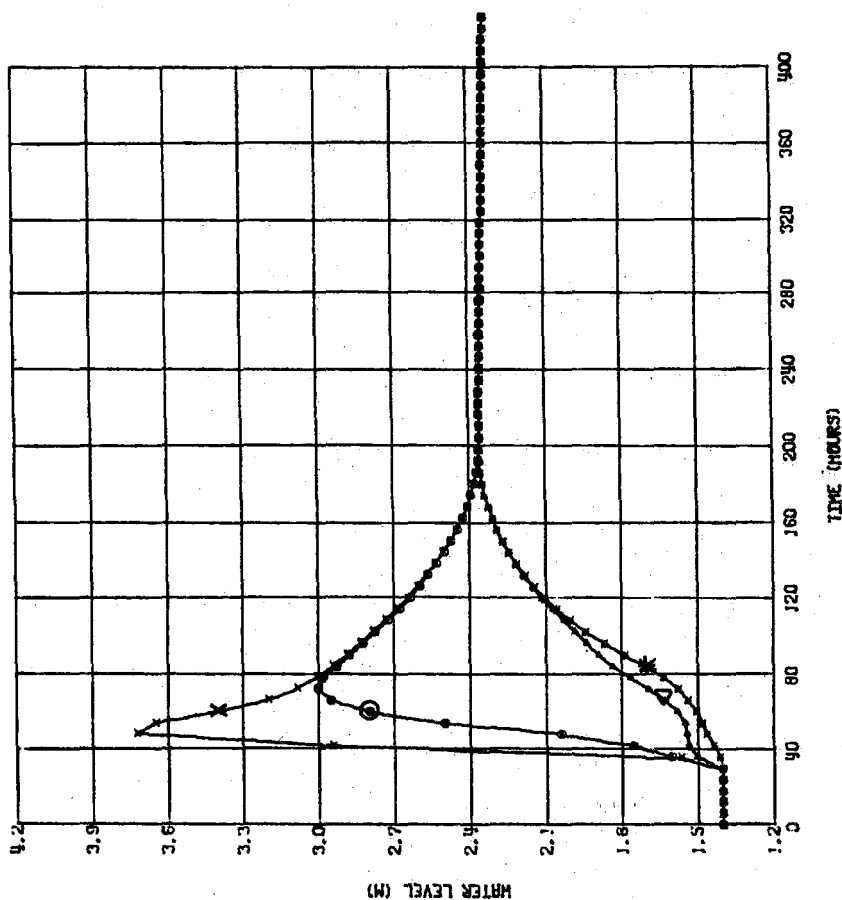
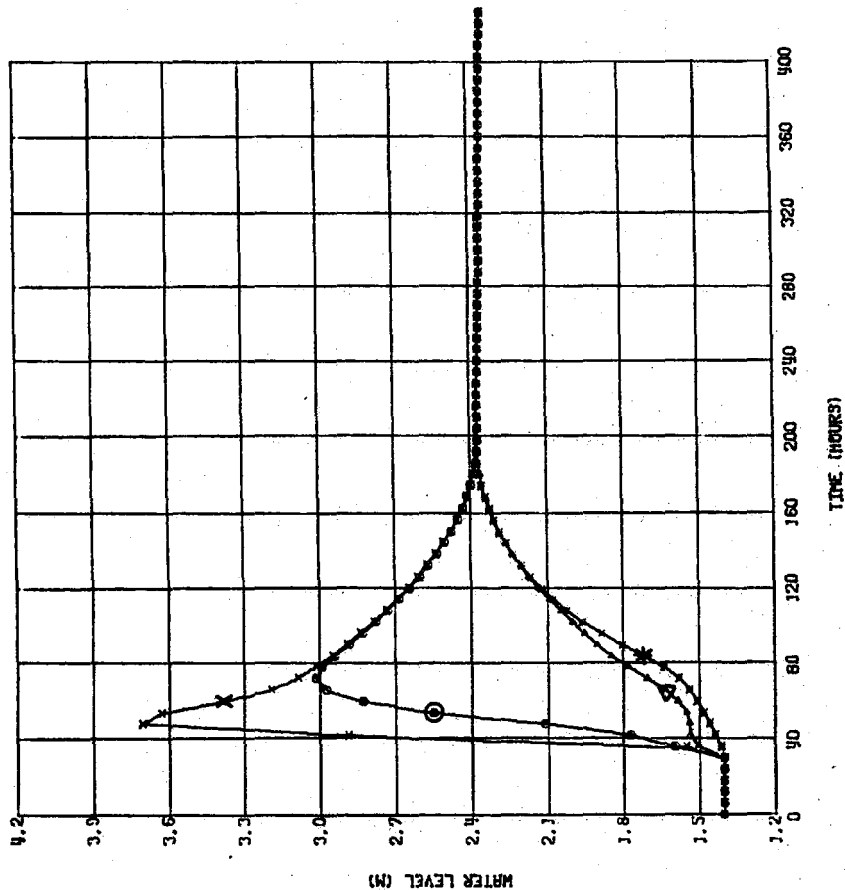
FLOOD: 1 IN 10 YEAR, MAX. DISCHARGE: 145.7 M³/S



TRACED : COMPLIT
CHECKED :
DATE : 1980-08-30
REF. : C/SEA 8113

WILDERNESS NUMERICAL STUDY
SERPENTINE DREDGED TO 0.0 M.
FLOOD: 1 IN 10 YEAR.

FIGURE
13.3b

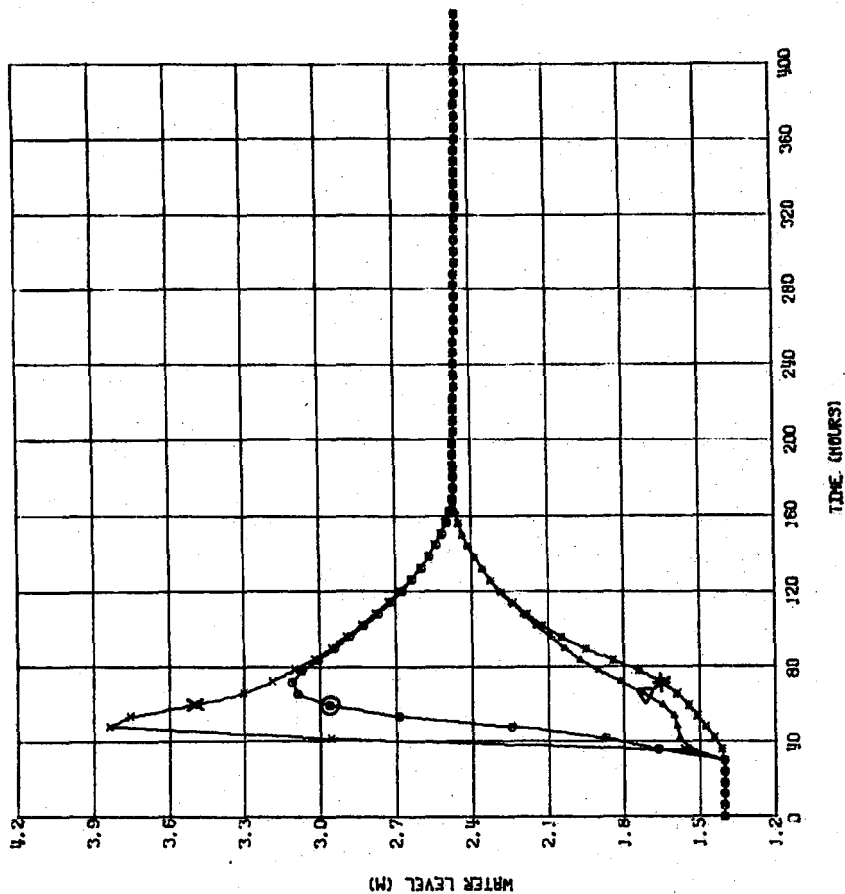


SCALE 1:17744

TRACED : COMPLIT
CHECKED :
DATE : 1980-08-30
REF. : C/SEA 8113

WILDERNESS NUMERICAL STUDY
SERPENTINE DREDGED TO 0.0 M.
FLOOD: 1 IN 20 YEAR.

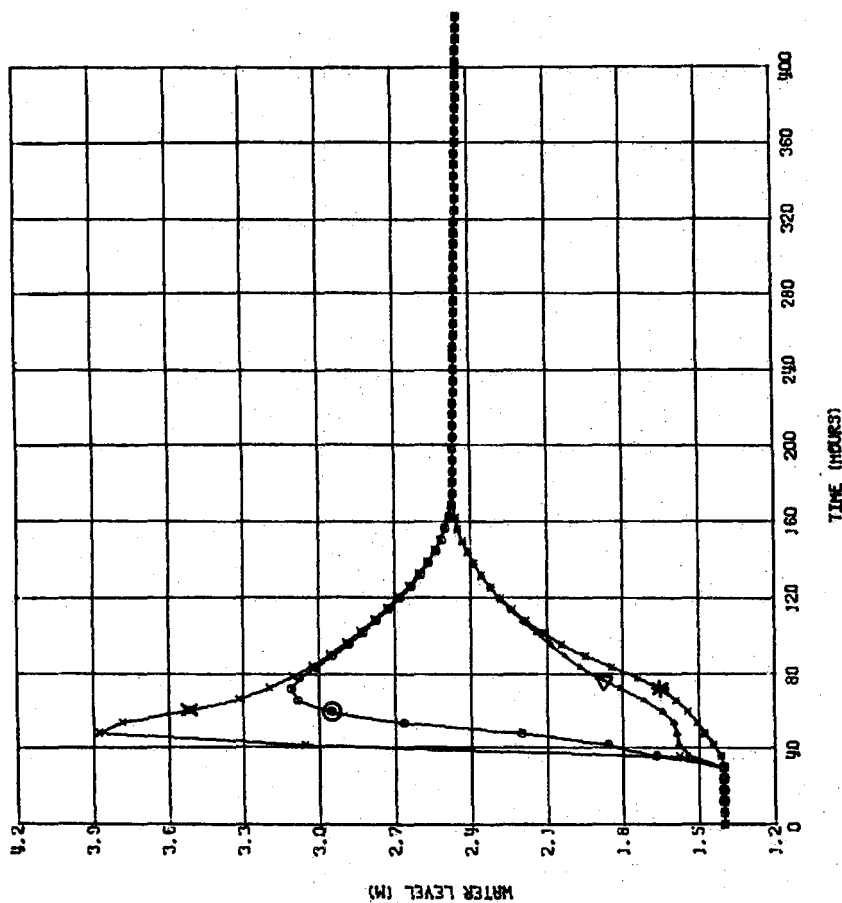
FIGURE
13.3c



MODEL RESULTS. SERPENTINE DREDGED TO 0.0 M TO MSL.

INITIAL LEVEL: 1.4 M.

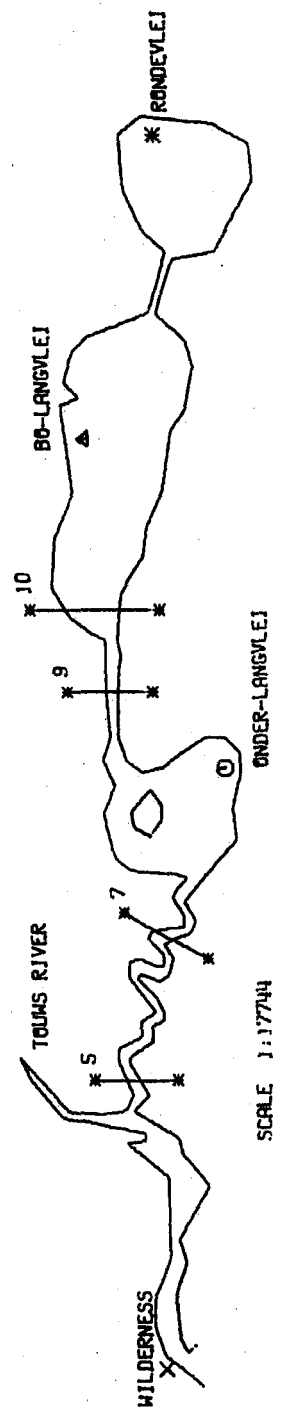
FLOOD: 1 IN 50 YEAR. MAX. DISCHARGE: 184.3 M³/S



MODEL RESULTS.

ORIGINAL LAYOUT. INITIAL LEVEL: 1.4 M TO MSL. *

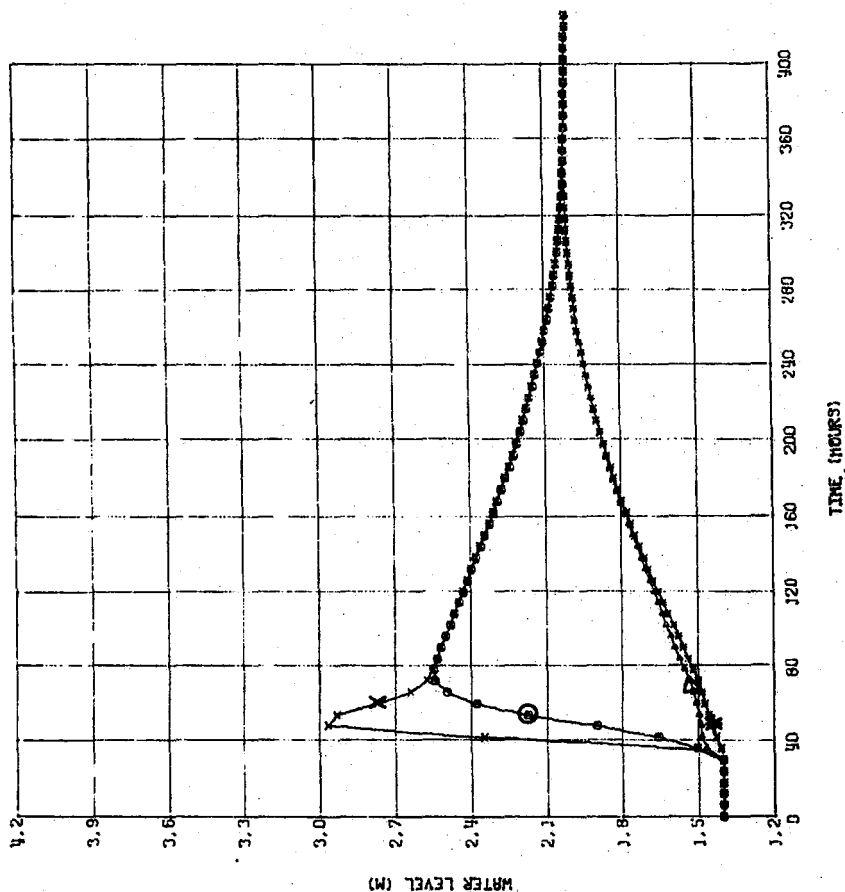
FLOOD: 1 IN 50 YEAR. MAX. DISCHARGE: 184.3 M³/S



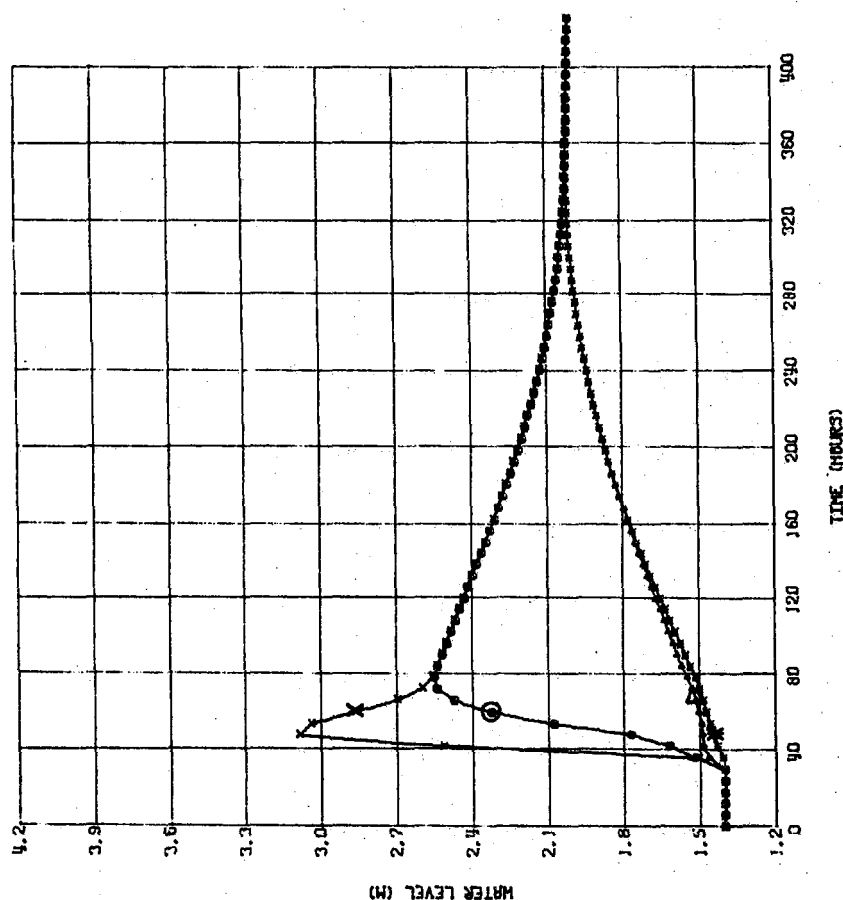
TRACED : COMPILOT
CHECKED :
DATE : 1980-08-30
REF. : C/SEA 8113

WILDERNESS NUMERICAL STUDY
SERPENTINE DREDGED TO 0.0 M.
FLOOD: 1 IN 50 YEAR.

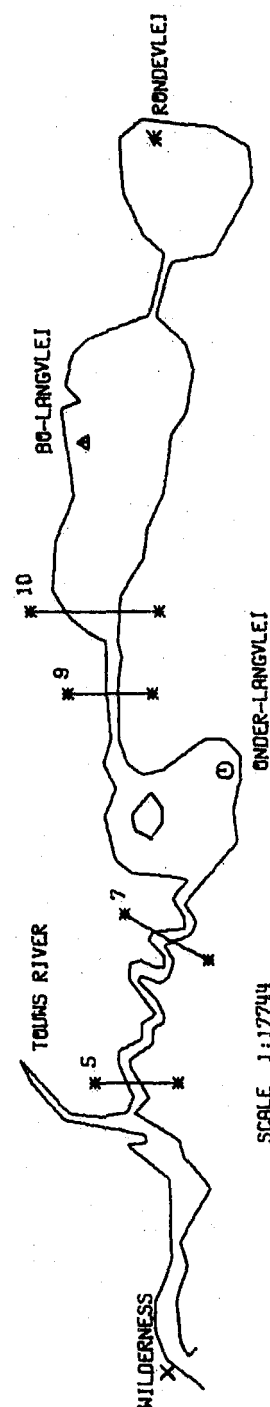
FIGURE
13.3d



MODEL RESULTS. SERPENTINE DREDGED TO -1 M. TO MSL.
 INITIAL LEVEL: 1.4 M.
 FLOOD: 1 IN 5 YEAR. MAX. DISCHARGE: 109.1 M³/S.



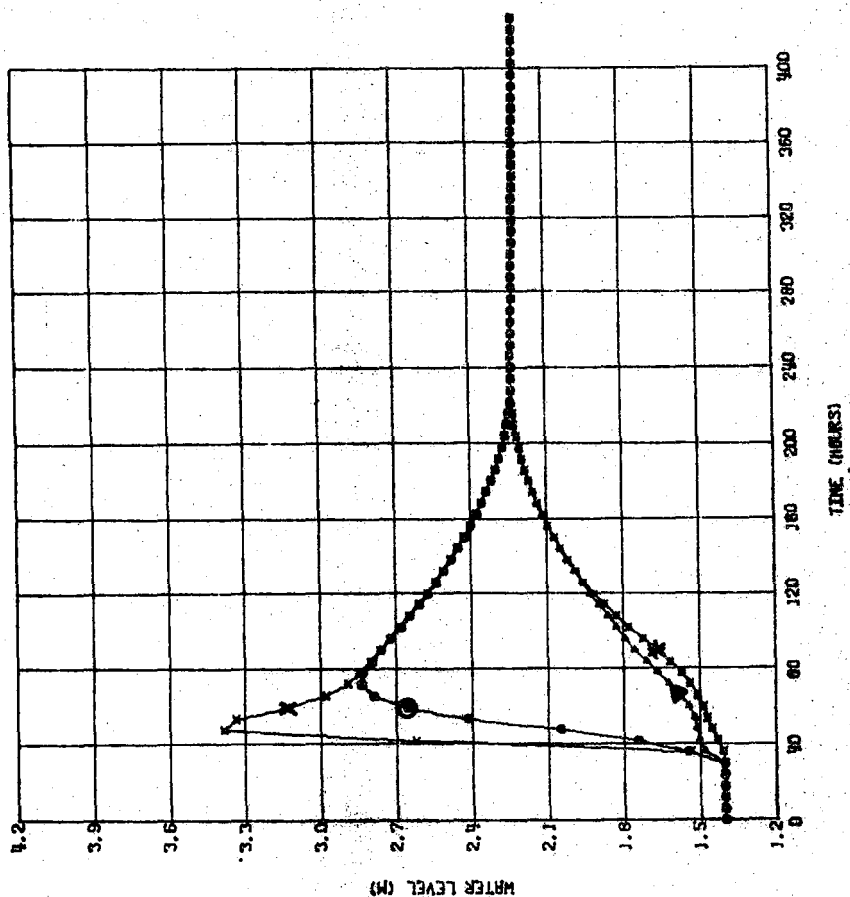
MODEL RESULTS.
 ORIGINAL LAYOUT. INITIAL LEVEL: 1.4 M TO MSL.
 FLOOD: 1 IN 5 YEAR. MAX. DISCHARGE: 109.1 M³/S.



TRACED : COMPLIT
 CHECKED :
 DATE : 1980-08-30
 REF. : C/SEA 8113

WILDERNESS NUMERICAL STUDY
 SERPENTINE DREDGED TO -1.0 M.
 FLOOD: 1 IN 5 YEAR.

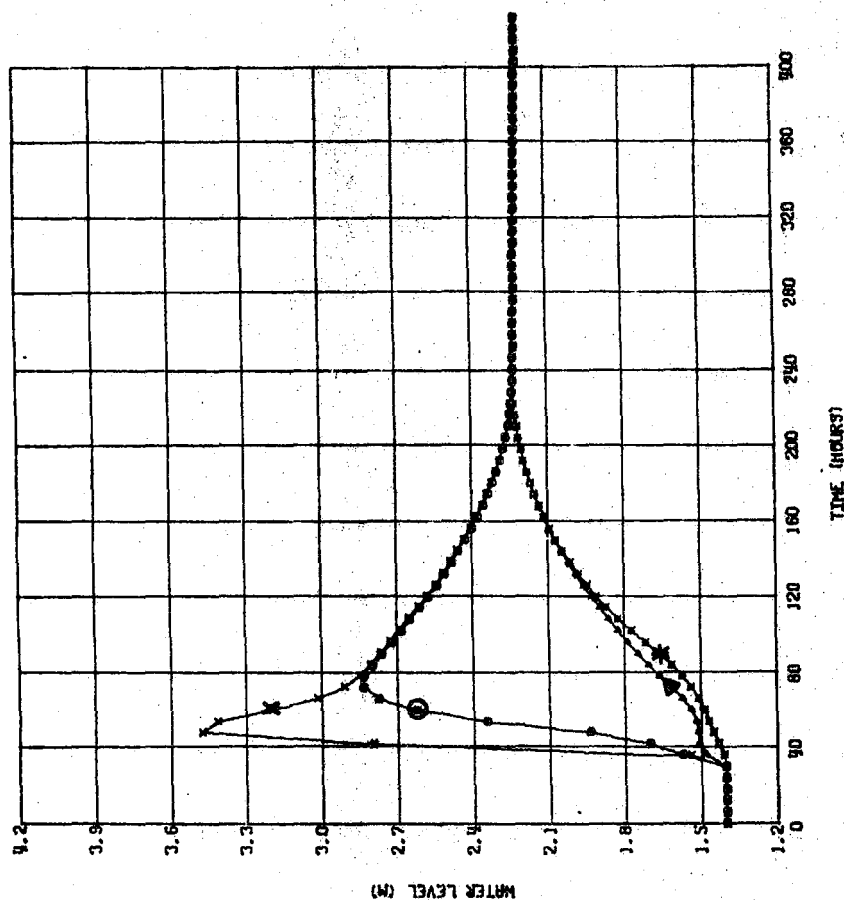
FIGURE
 13.4a



MODEL RESULTS. SERPENTINE DREDGED TO -1.0 M. TO MSL.

INITIAL LEVEL: 1.4 M.

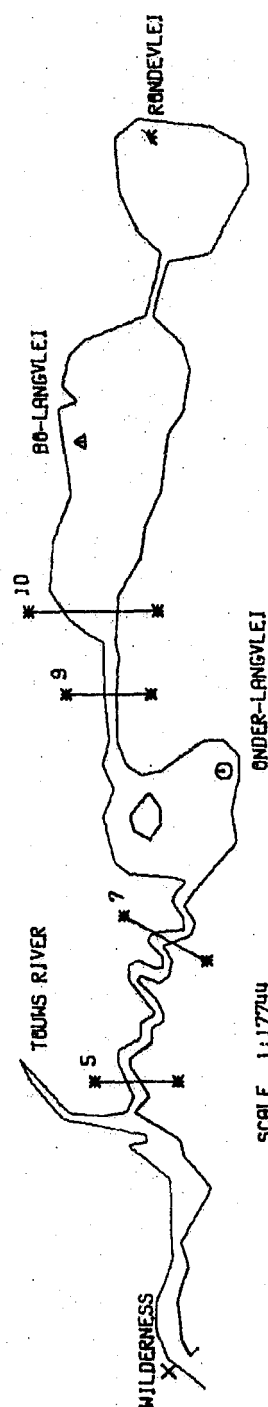
FLOOD: 1 IN 10 YEAR. MAX. DISCHARGE: 145.7 M³/S.



MODEL RESULTS.

ORIGINAL LAYOUT. INITIAL LEVEL: 1.4 M TO MSL.

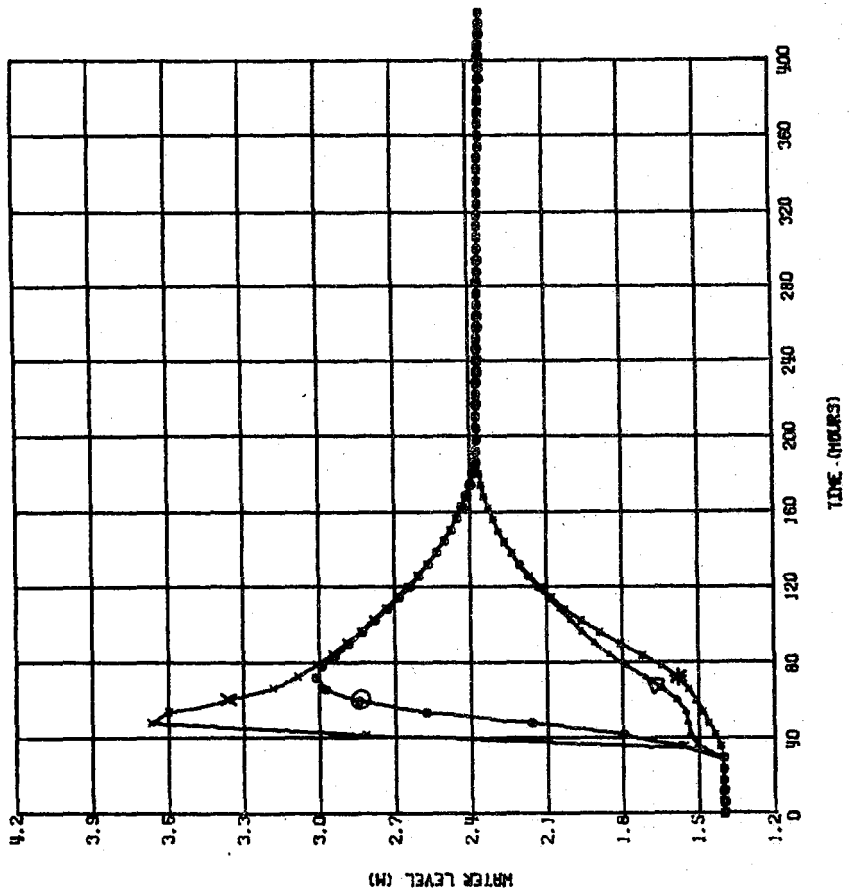
FLOOD: 1 IN 10 YR. MAX. DISCHARGE: 145.7 M³/S.



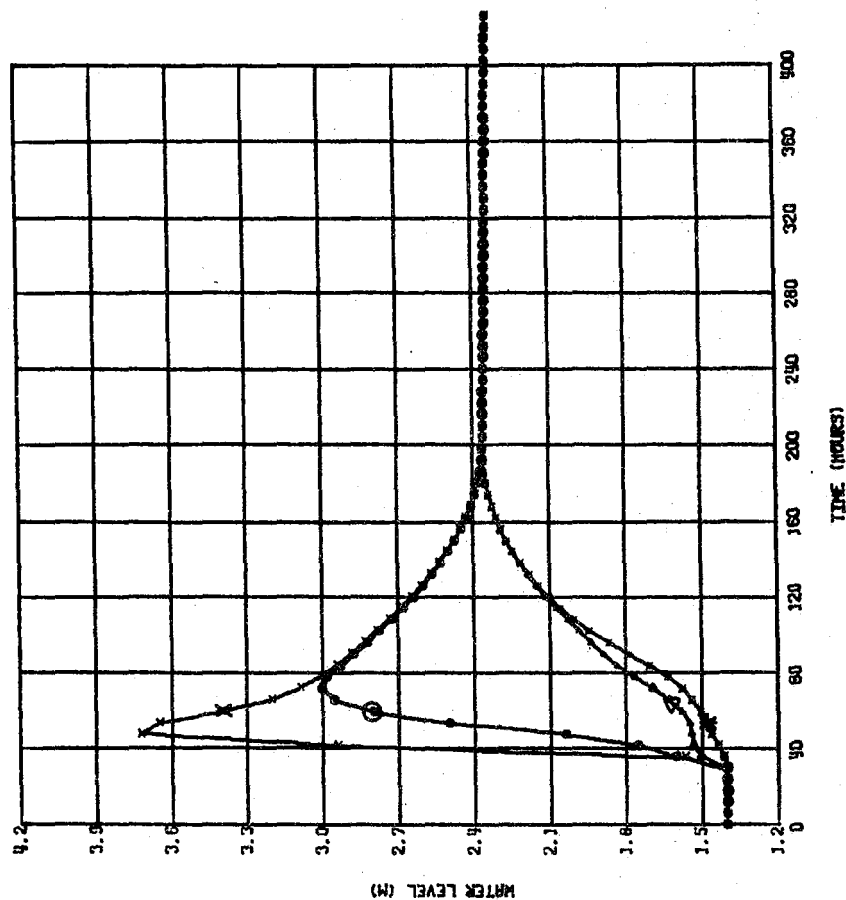
TRACED : COMLOT
CHECKED :
DATE : 1980-08-30
REF. : C/SEA 8113

WILDERNESS NUMERICAL STUDY
SERPENTINE DREDGED TO -1.0 M.
FLOOD: 1 IN 10 YEAR.

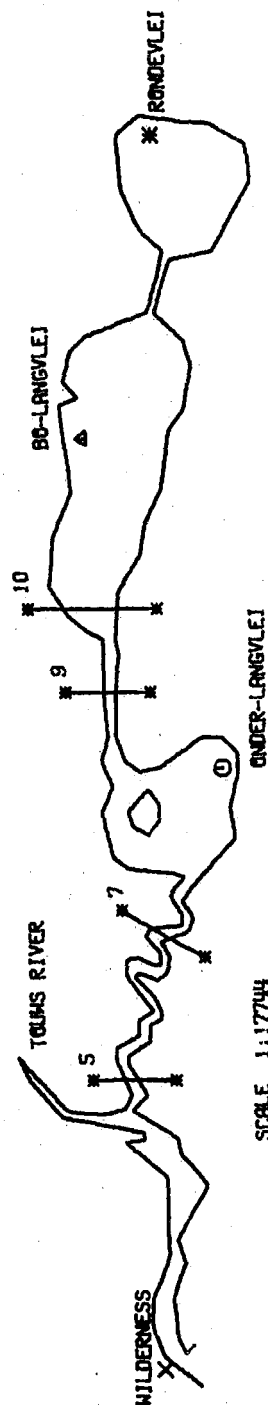
FIGURE
13.4b



MODEL RESULTS, SERPENTINE DREDGED TO -1 M. TO MSL.
 INITIAL LEVEL: 1.4 M.
 FLOOD : 1 IN 20 YEAR, MAX. DISCHARGE: 170.4 M³/S.



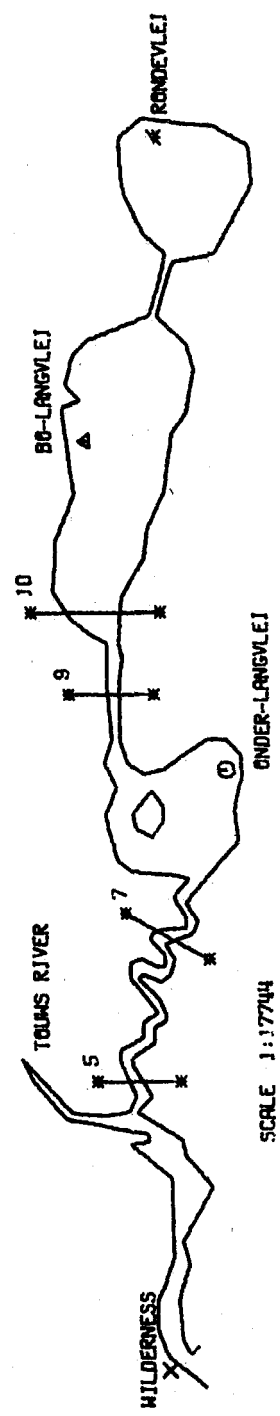
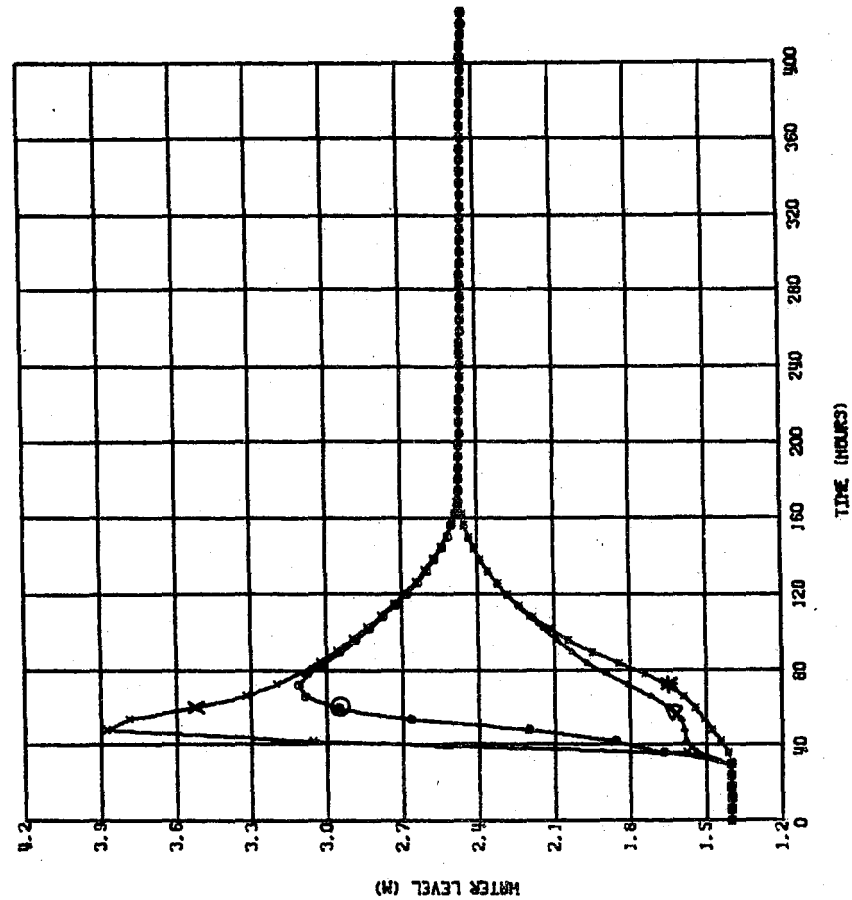
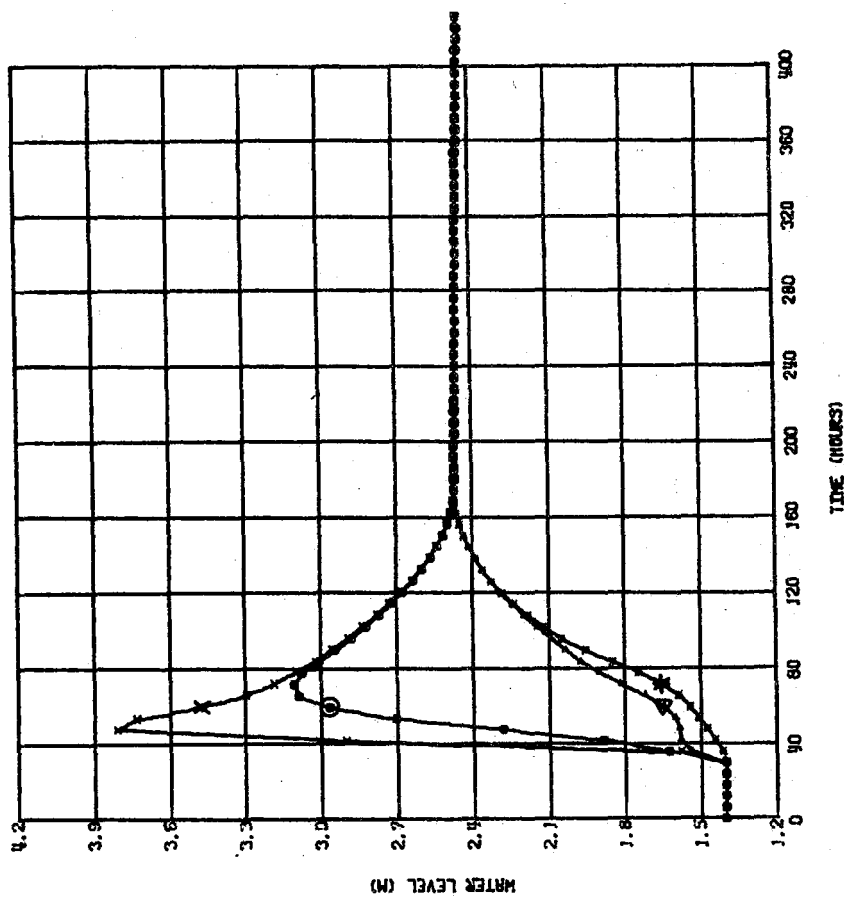
MODEL RESULTS.
 ORIGINAL LAYOUT, INITIAL LEVEL : 1.4 M TO MSL.
 FLOOD : 1 IN 20 YEAR, MAX. DISCHARGE: 170.4 M³/S.



TRACED : COMPLIT
 CHECKED :
 DATE : 1980-08-30
 REF. : C/SEA 8/13

WILDERNESS NUMERICAL STUDY
 SERPENTINE DREDGED TO -1.0 M.
 FLOOD: 1 IN 20 YEAR.

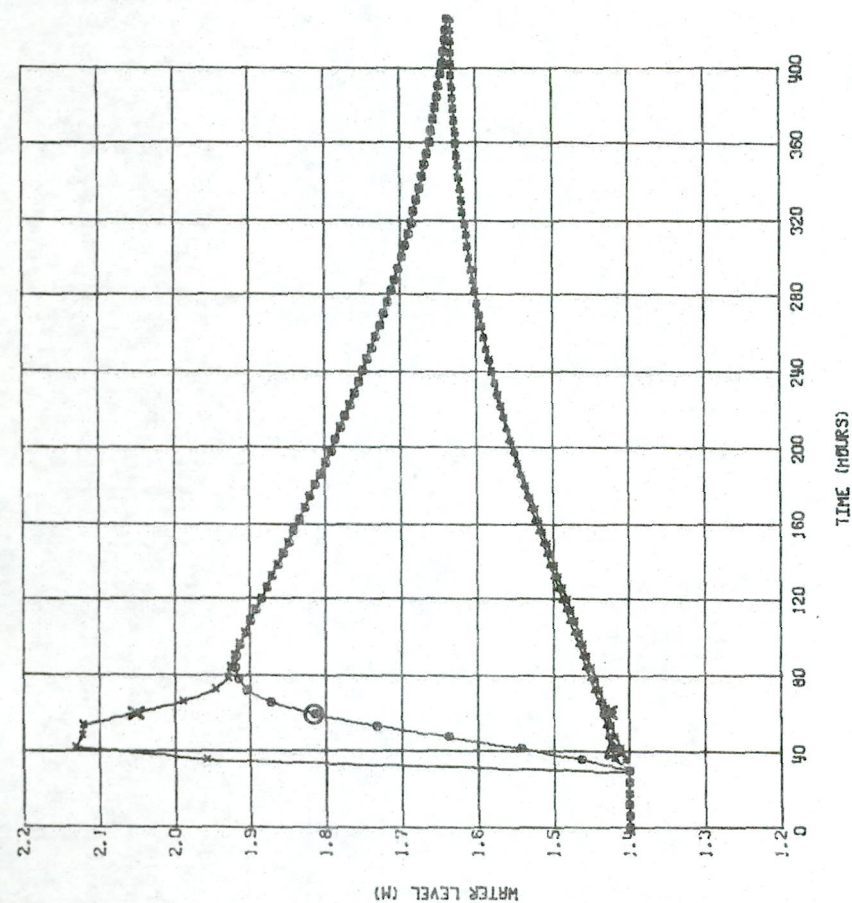
FIGURE
 13.4c



TRACED : COMPILOT
CHECKED :
DATE : 1980-08-30
REF. : C/SEA 8113

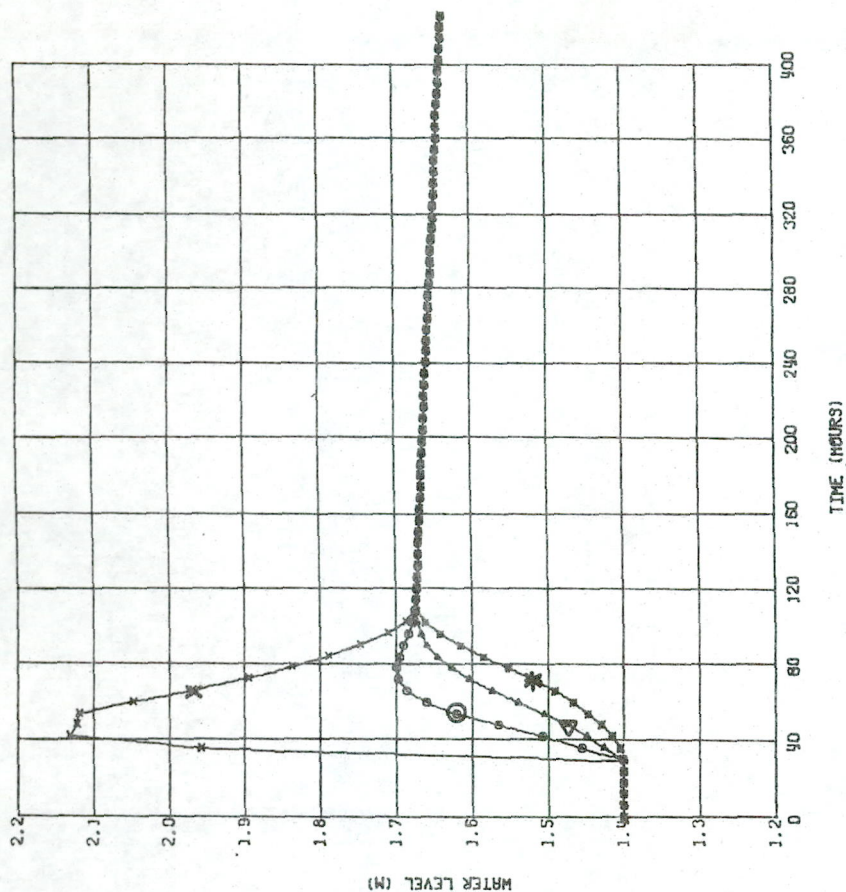
WILDERNESS NUMERICAL STUDY
SERPENTINE DREDGED TO -1.0 M.
FLOOD: 1 IN 50 YEAR.

FIGURE
13.4d



MODEL RESULTS.
ORIGINAL LAYOUT.

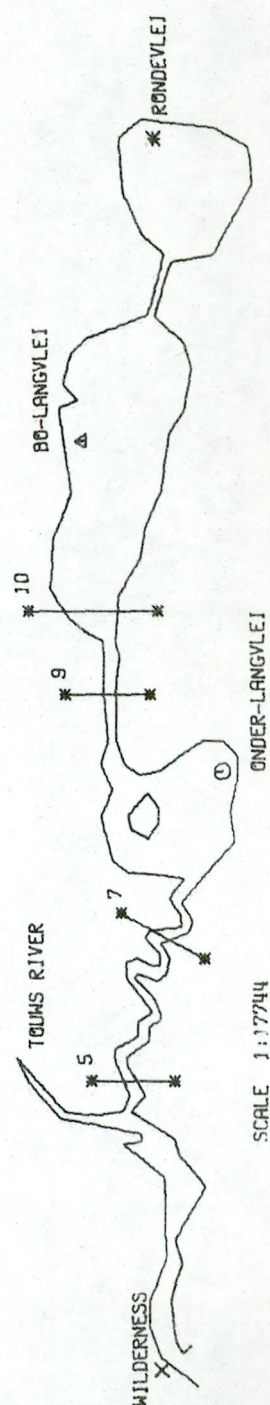
FLOOD : JANUARY 1979. INITIAL LEVEL : 1.40 M.



MODEL RESULTS. LONG CHANNEL DREDGED TO 0.0 M (MSL)

SECTIONS 9 AND 10.

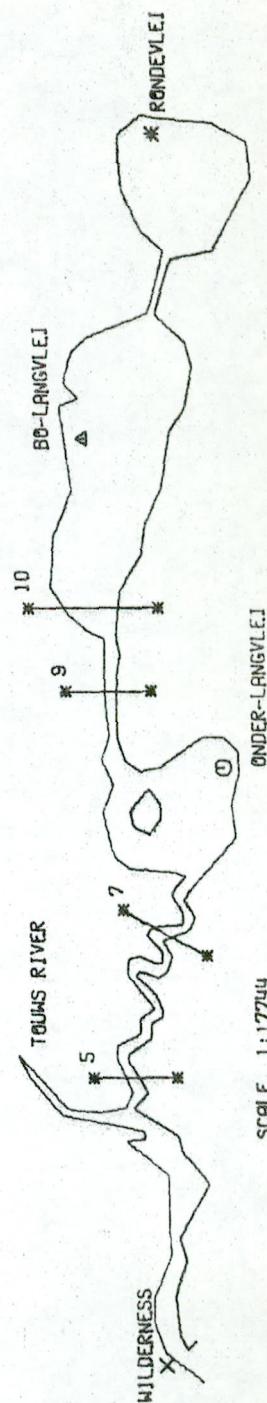
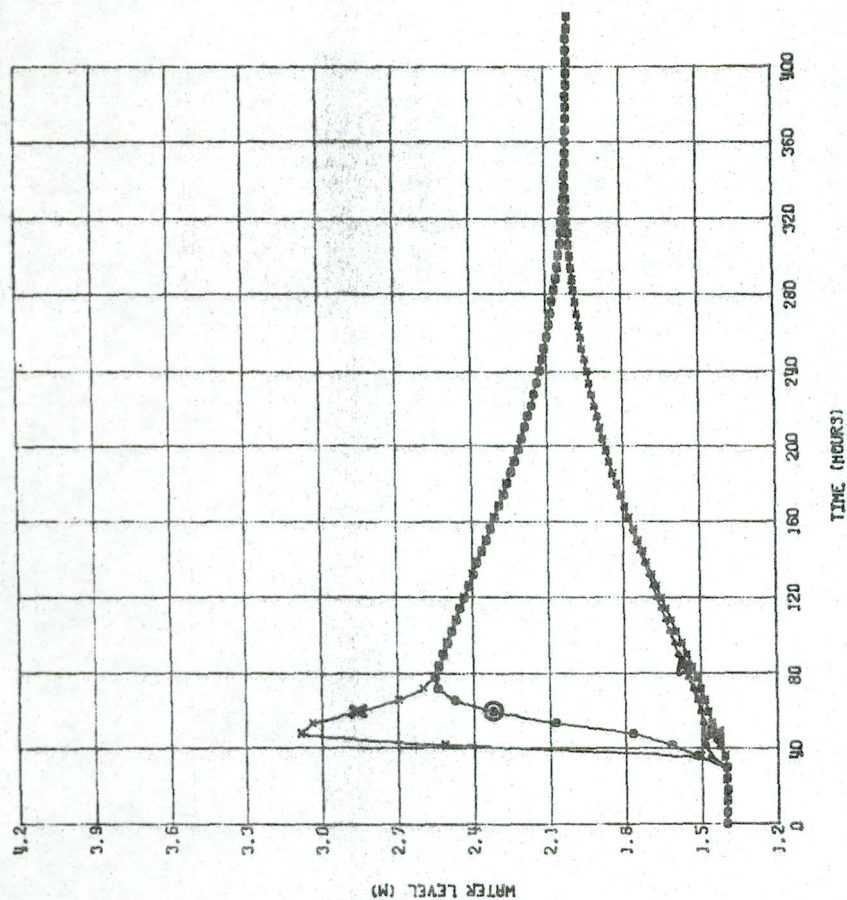
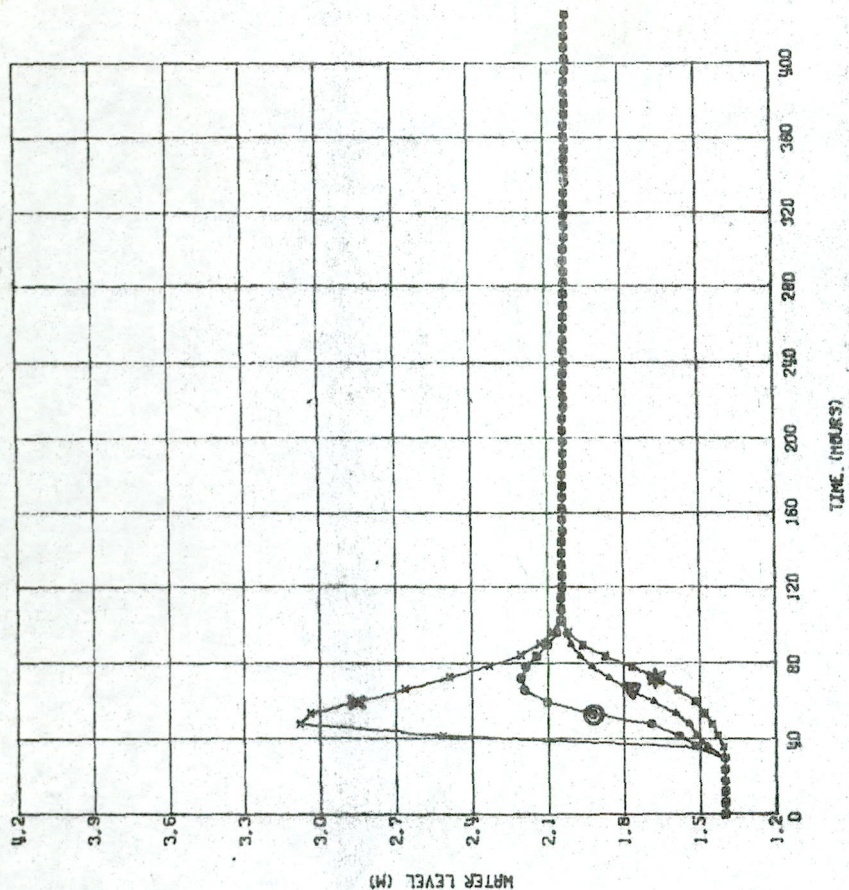
FLOOD : JANUARY 1979. INITIAL LEVEL 1.40 M.



PLACED : COMPLET
CHECKED :
: 1980-08-30
C/SEA 8113

WILDERNESS NUMERICAL STUDY
LONG CHANNEL DREDGED.
PROTOTYPE DATA - JANUARY 1979.

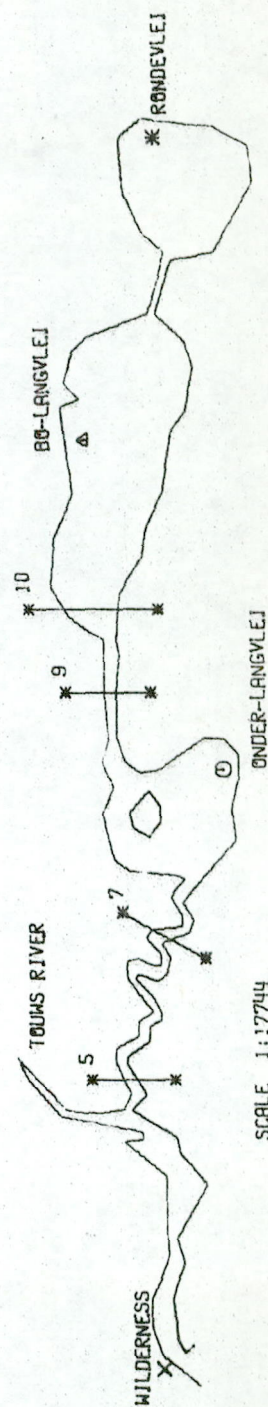
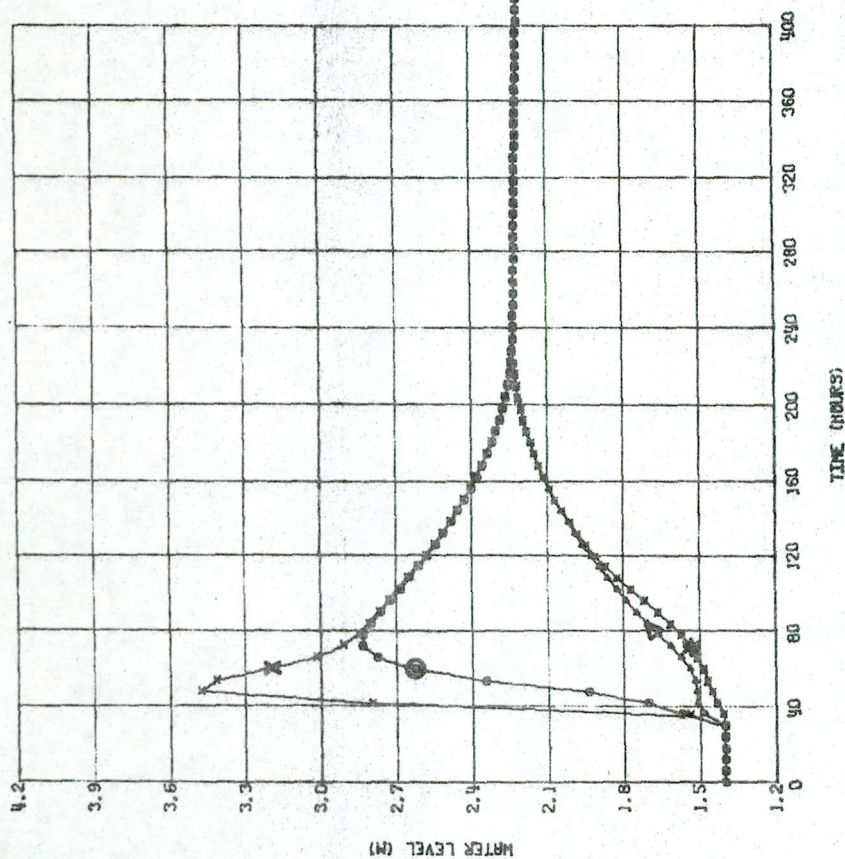
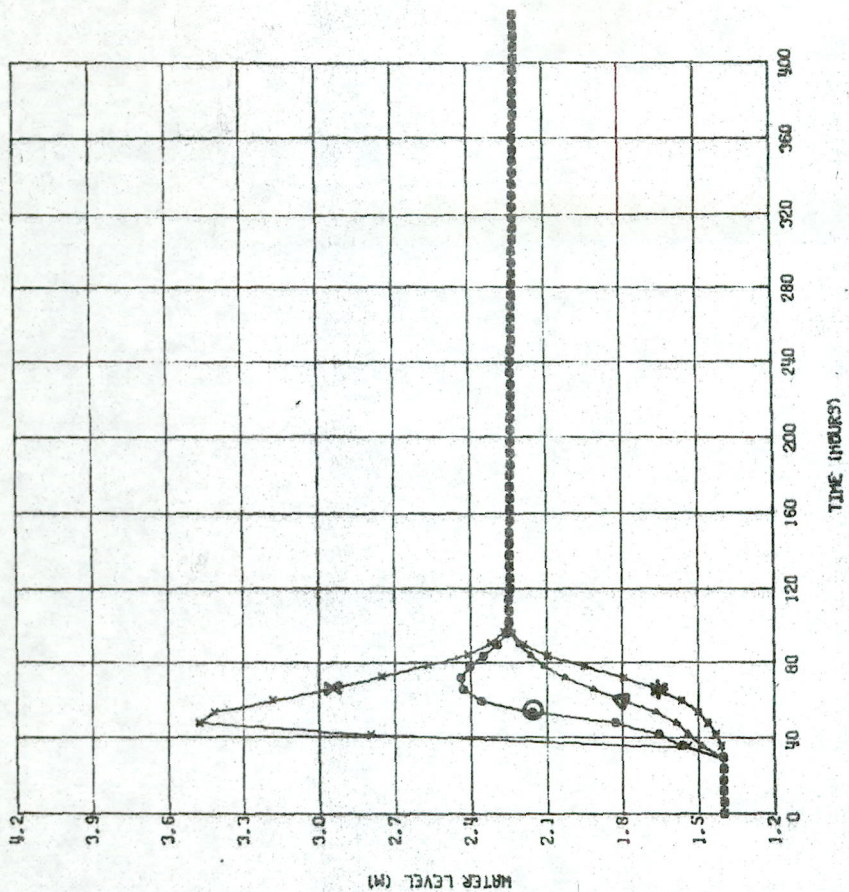
FIGURE
14.1



TRACED : COMPILOT
CHECKED :
1980-08-30
C/SEA 8113

WILDERNESS NUMERICAL STUDY
LONG CHANNEL DREDGED TO 0.0 M.
FLOOD: 1 IN 5 YEAR.

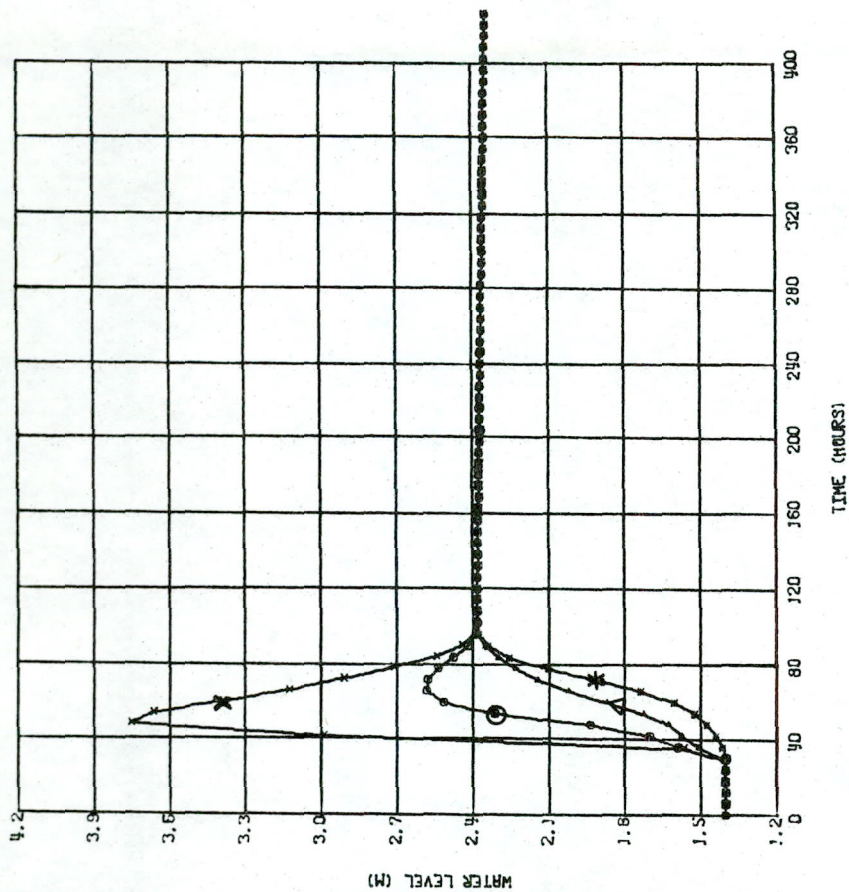
FIGURE
14.2a



TRACED : COMLOT
CKED :
: 1980-08-30
C/SEA 8113

WILDERNESS NUMERICAL STUDY
LONG CHANNEL DREDGED TO 0.0 M.
FLOOD: 1 IN 10 YEAR.

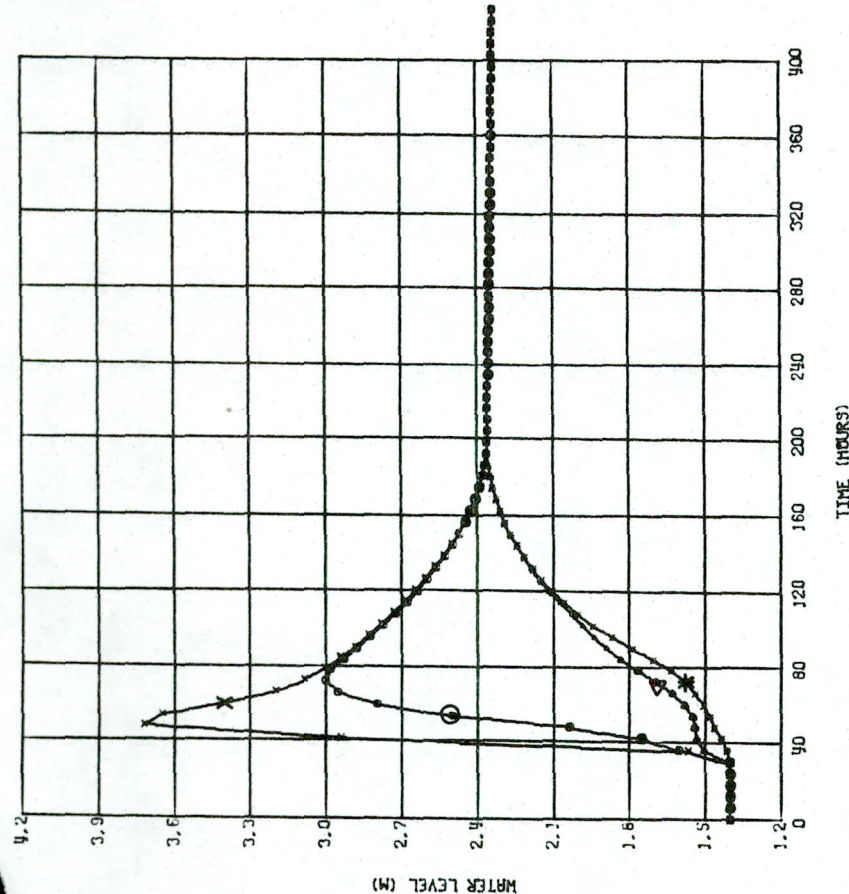
FIGURE
14.2b



MODEL RESULTS. LONG CHANNEL DREDGED TO 0.0 M TO MSL.

INITIAL LEVEL: 1.4 M.

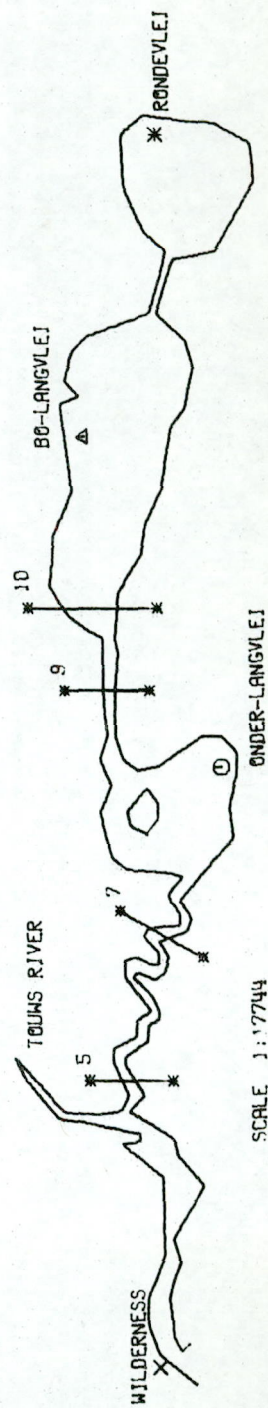
FLOOD: 1 IN 20 YEAR. MAX. DISCHARGE: 170.4 M³/S.



MODEL RESULTS.

ORIGINAL LAYOUT. INITIAL LEVEL: 1.4 M TO MSL.

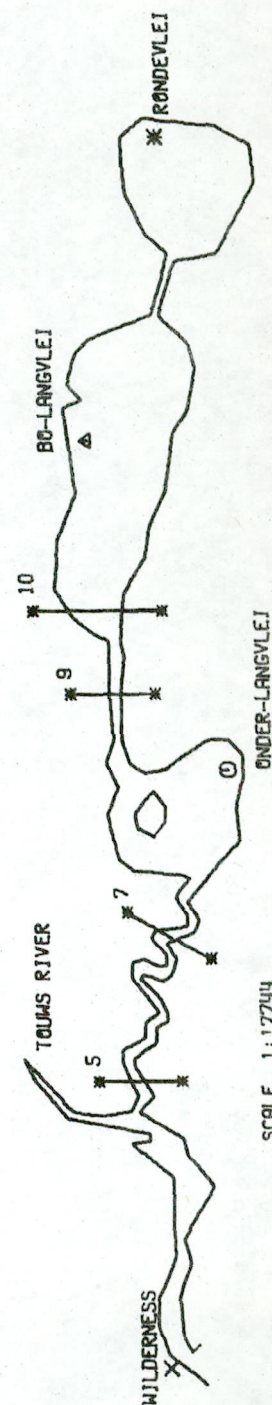
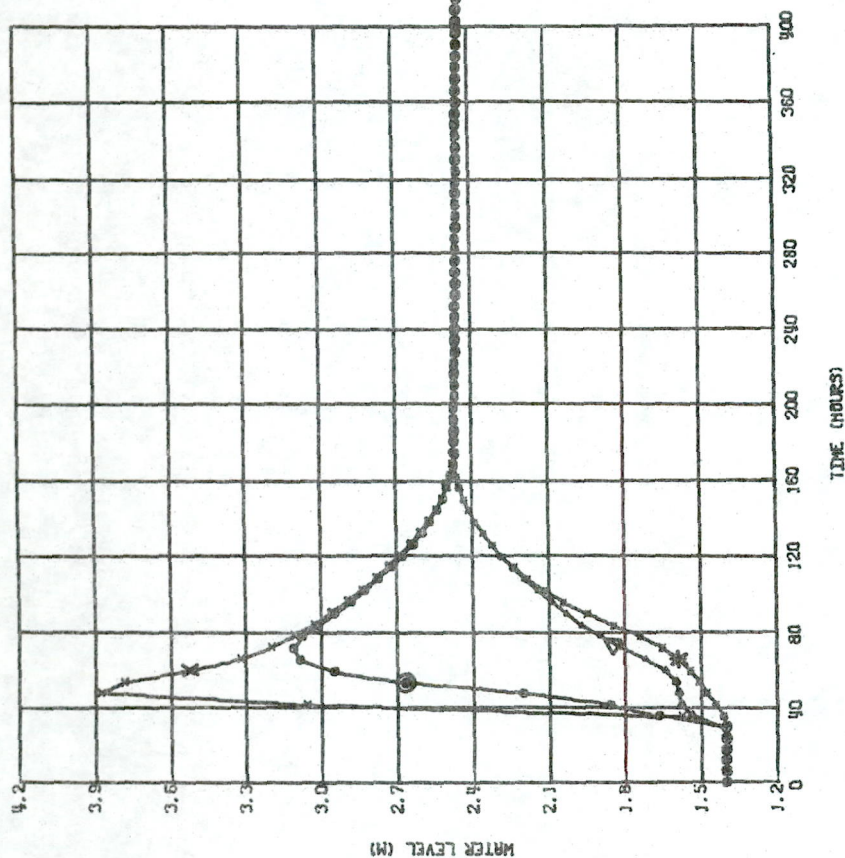
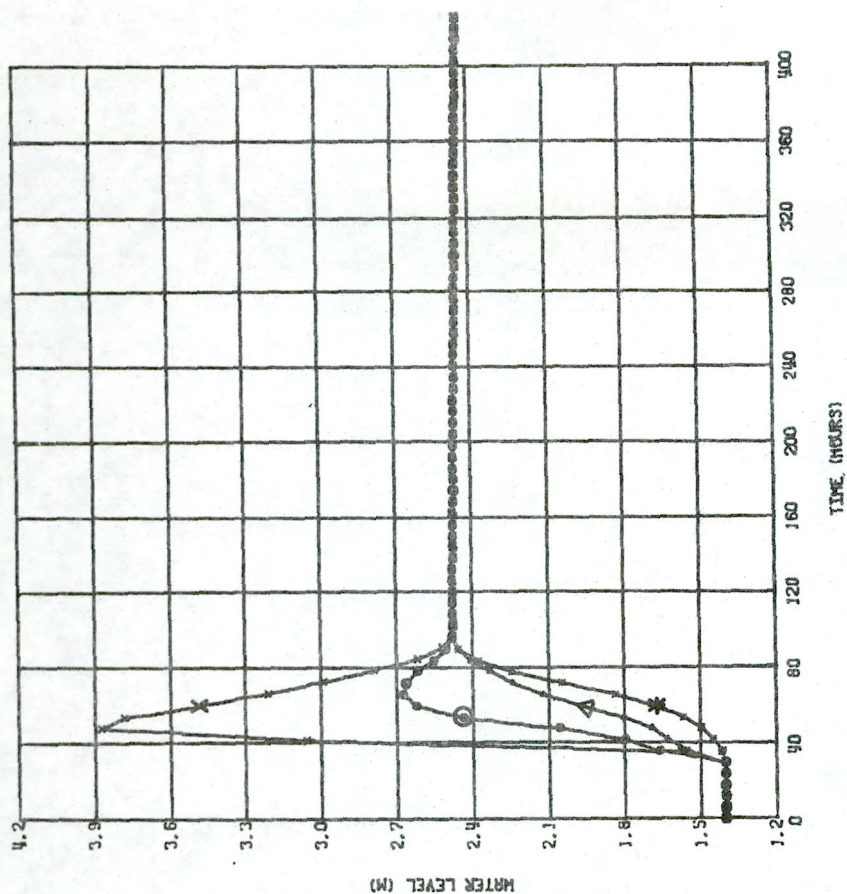
FLOOD: 1 IN 20 YEAR. MAX. DISCHARGE: 170.4 M³/S.



ED : COMLOT
ED :
1980-08-30
/SEP 8/13

WILDERNESS NUMERICAL STUDY
LONG CHANNEL DREDGED TO 0.0 M.
FLOOD: 1 IN 20 YEAR.

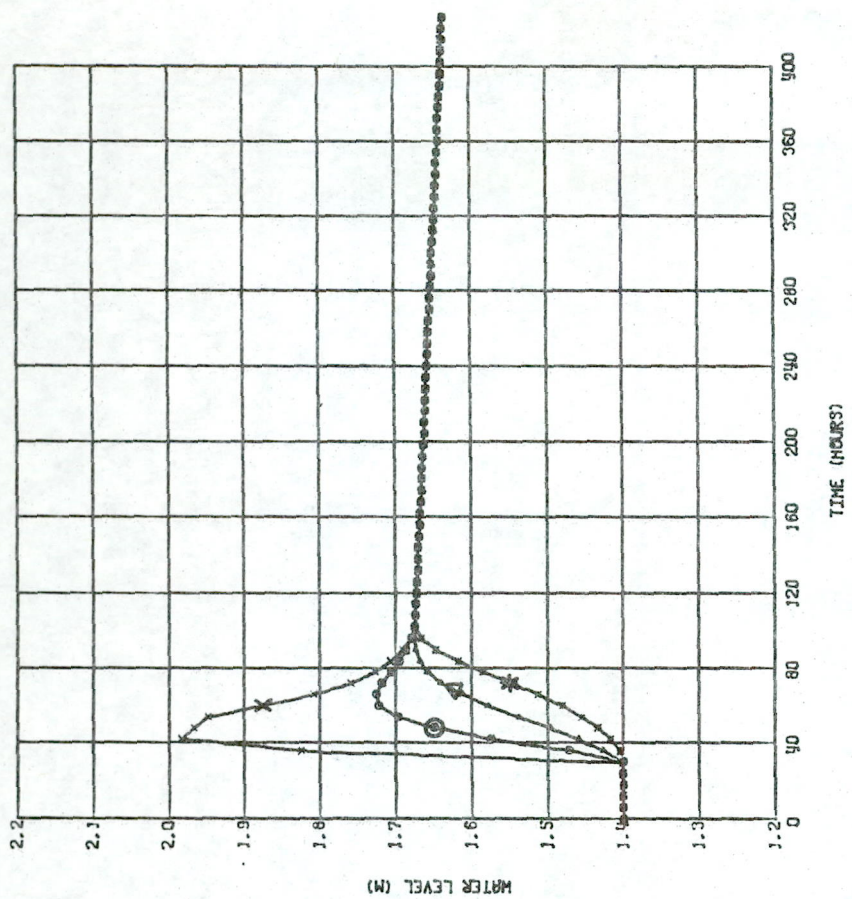
FIGURE
14.2c



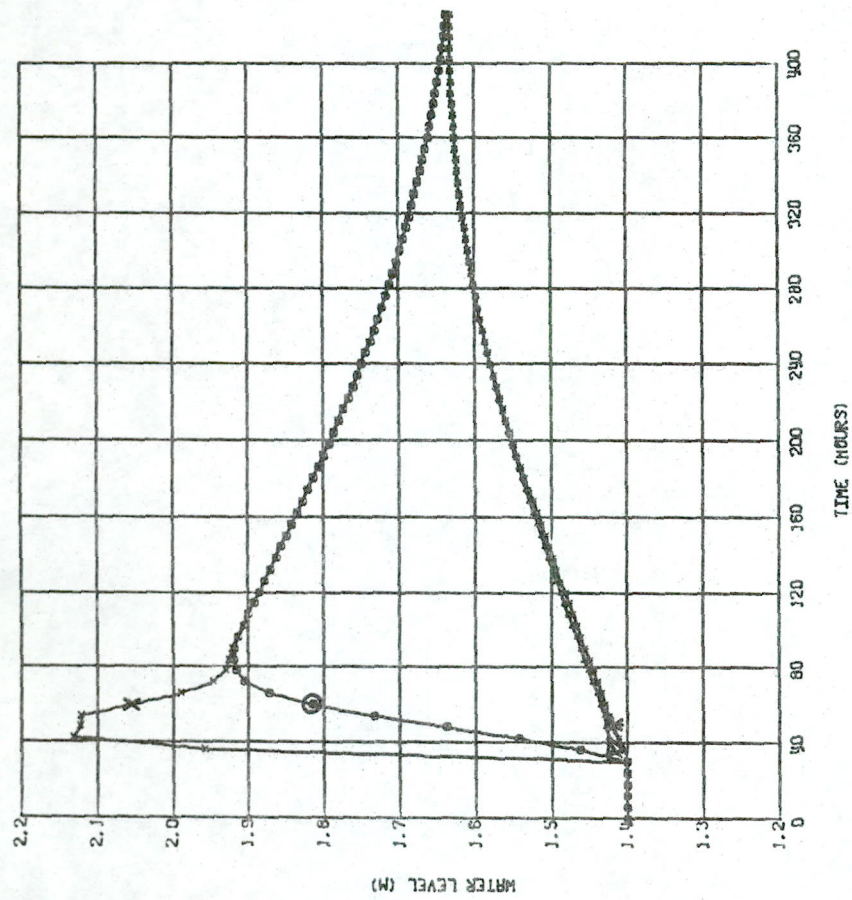
TRACED: COMPILOT
CHECKED:
DATE: 1980-08-30
C/SEA 8113

WILDERNESS NUMERICAL STUDY
LONG CHANNEL DREDGED TO 0.0 M.
FLOOD: 1 IN 50 YEAR.

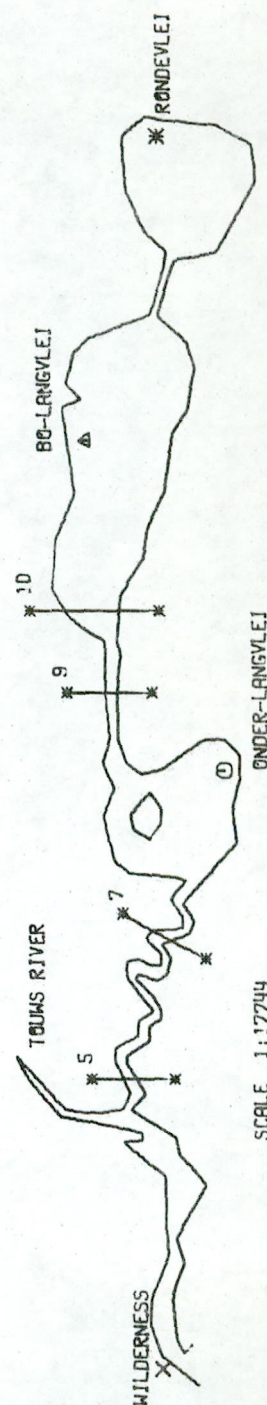
FIGURE
14.2d



MODEL RESULTS, SERPENTINE DREDGED TO -1.0M (SECTIONS 5+7) AND LONG CHANNEL TO 0.0M (SEC. 9+10)
FLOOD : JANUARY 1979 INITIAL LEVEL : 1.4 M



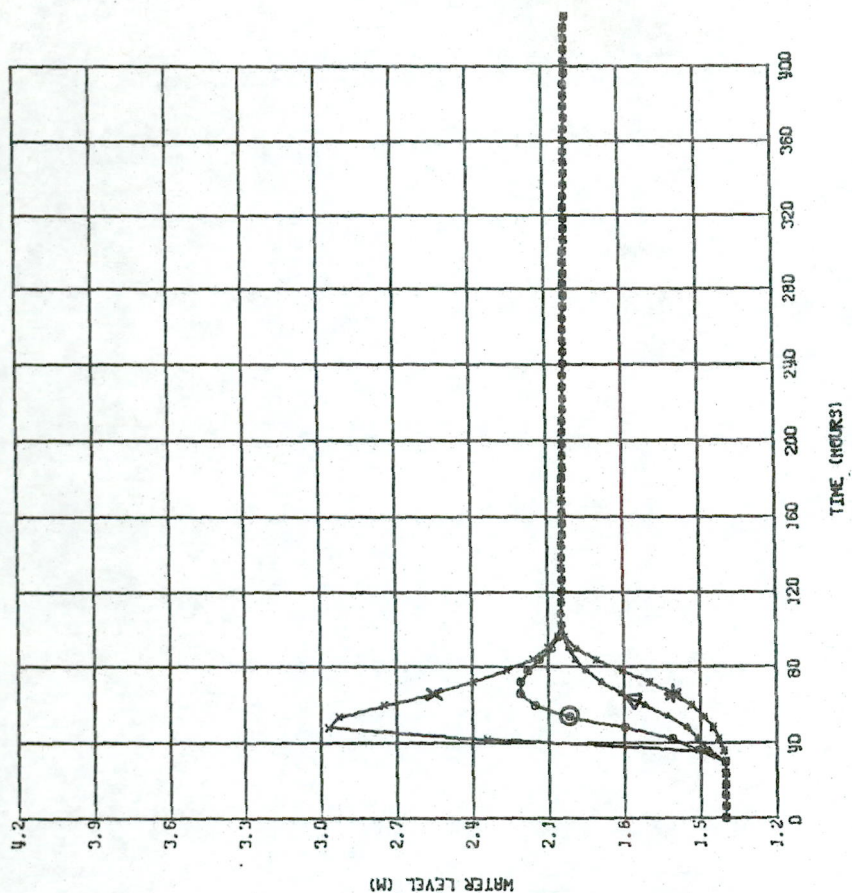
MODEL RESULTS
ORIGINAL LAYOUT
FLOOD : JANUARY 1979 INITIAL LEVEL : 1.4 M



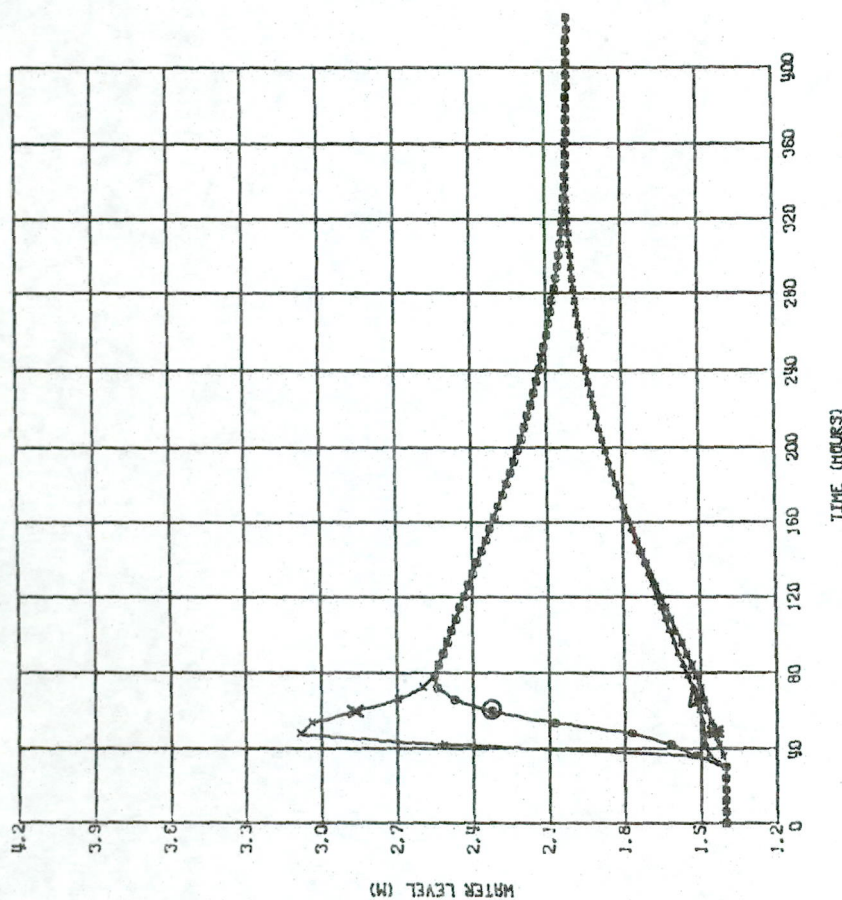
PREPARED : COMPILOT
CHECKED :
DATE : 1980-08-30
C/SEA 8113

WILDERNESS NUMERICAL STUDY
SERPENTINE AND LONG CHANNEL DREDGED
PROTOTYPE DATA - JANUARY 1979.

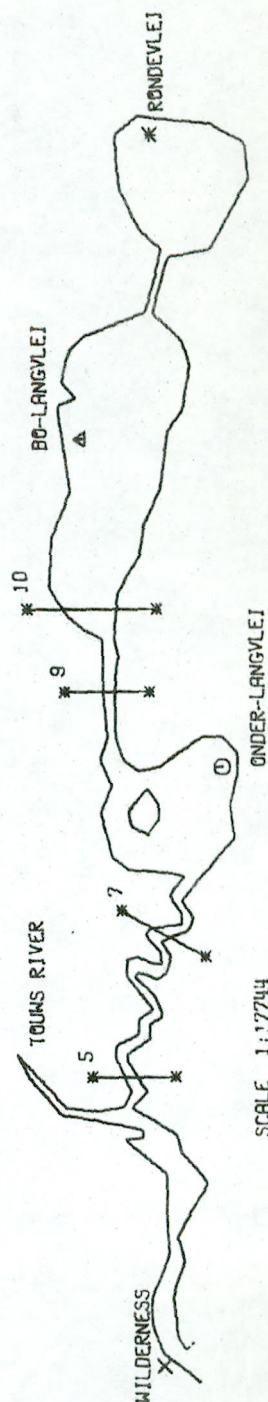
FIGURE
15.1



MODEL RESULTS. SECTIONS 5+7 DREDGED TO -1.0 M AND
9+10 TO 0.0 M. INITIAL LEVEL : 1.4 M TO MSL.
FLOOD : 1 IN 5 YEAR. MAX DISCHARGE: 109.1 M³/S *



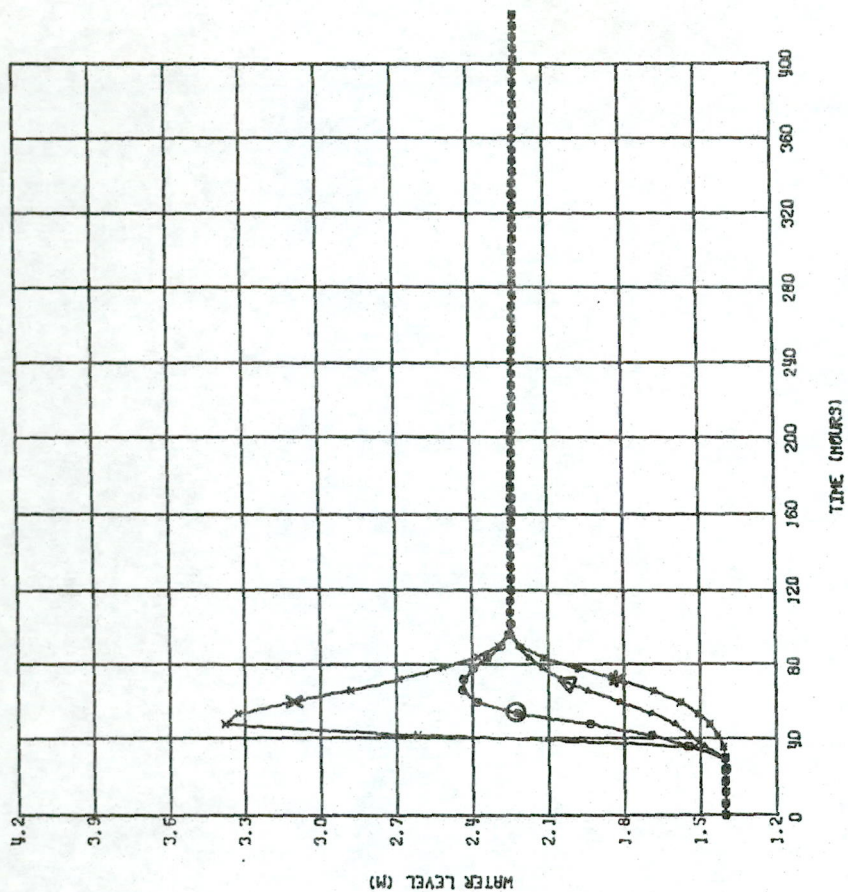
MODEL RESULTS.
ORIGINAL LAYOUT. INITIAL LEVEL : 1.4 M TO MSL.
FLOOD : 1 IN 5 YEAR. MAX DISCHARGE: 109.1 M³/S *



ERACED : COMPILOT
CKED :
: 1980-08-30
C/SEA 8113

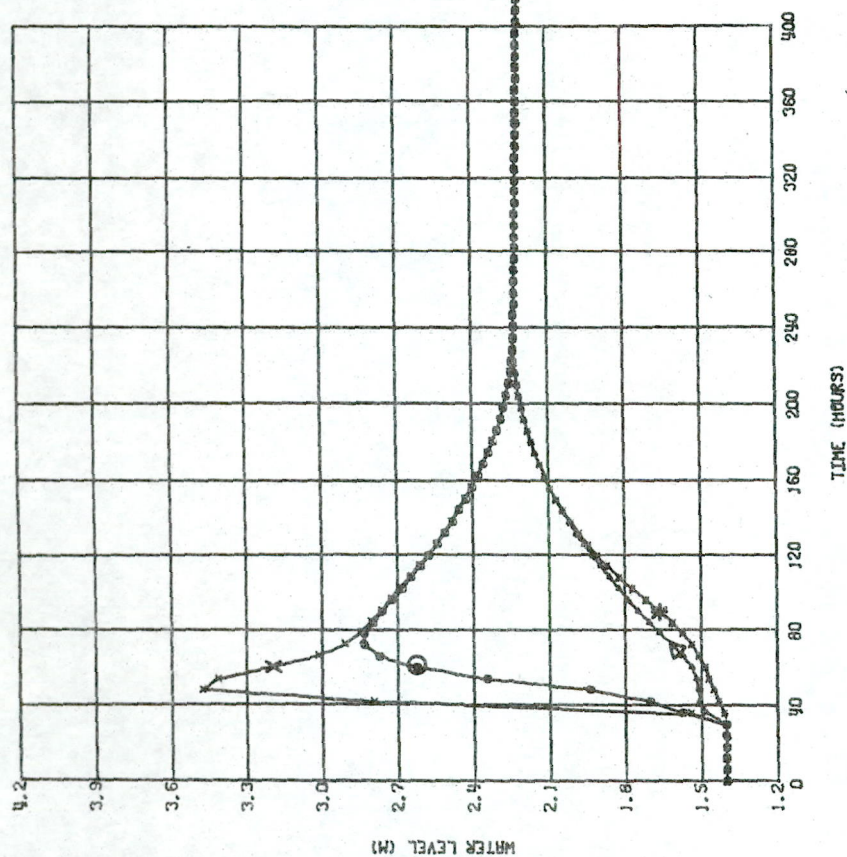
WILDERNESS NUMERICAL STUDY
ORIGINAL LAYOUT AND DREDGED SYSTEM.
FLOOD: 1 IN 5 YEAR.

FIGURE
15.2a



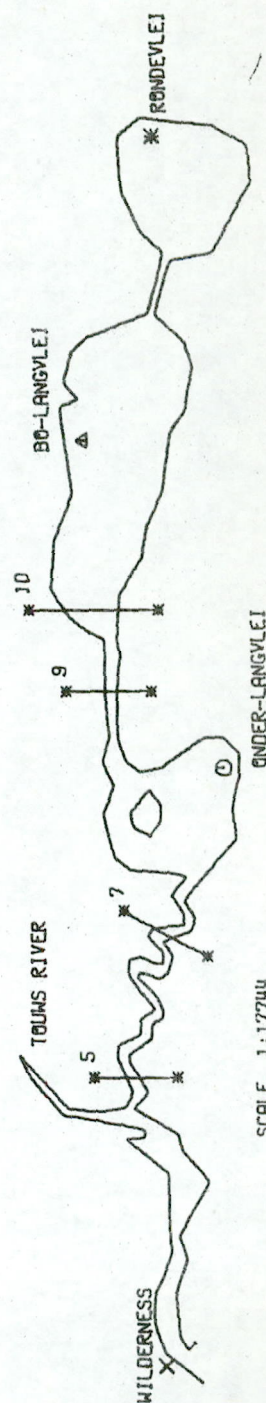
TIME (HOURS)

MODEL RESULTS, SECTIONS 5+7 DREDGED TO -1.0 M AND
9+10 TO 0.0 M. INITIAL LEVEL : 1.4 M TO MSL.
FLOOD : 1 IN 10 YEAR. MAX DISCHARGE: 145.7 M³/S



TIME (HOURS)

MODEL RESULTS.
ORIGINAL LAYOUT. INITIAL LEVEL : 1.4 M TO MSL.
FLOOD : 1 IN 10 YEAR. MAX DISCHARGE: 145.7 M³/S

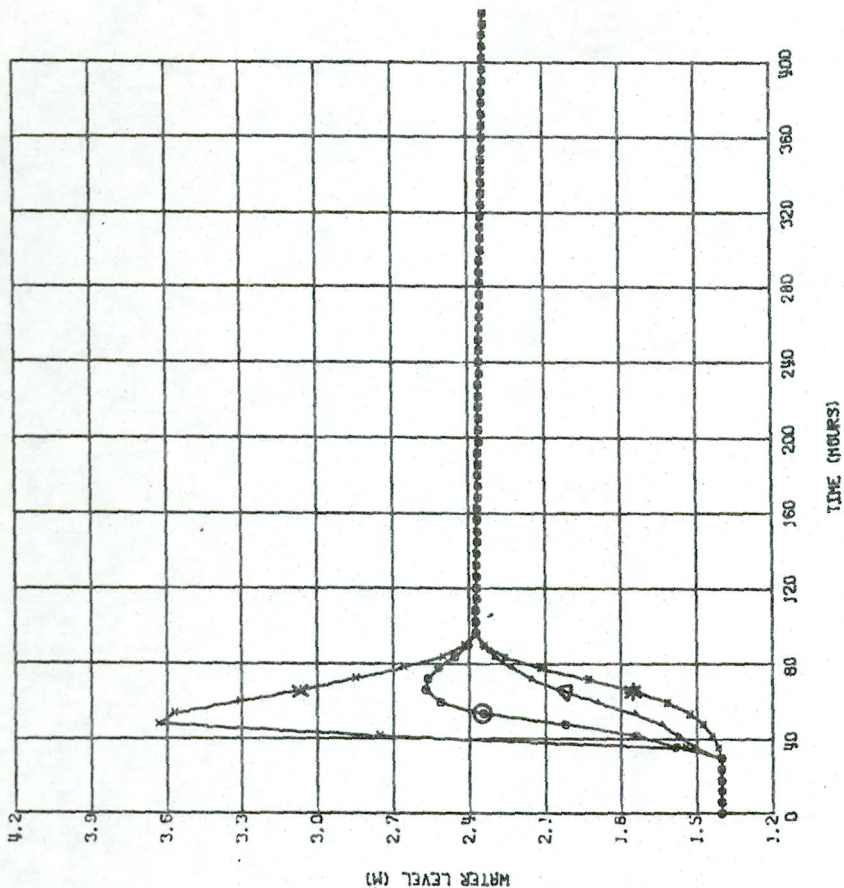


SCALE 1:17744

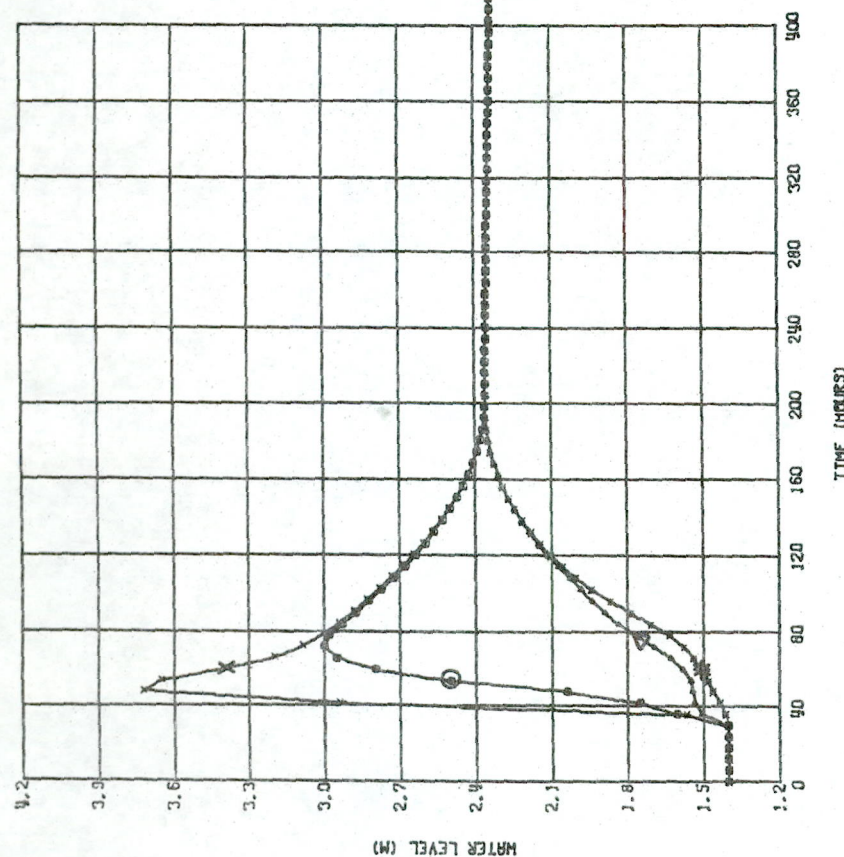
TRACED : COMLOT
CHECKED :
: 1980-08-30
: C/SEA 8113

WILDERNESS NUMERICAL STUDY
ORIGINAL LAYOUT AND DREDGED SYSTEM.
FLOOD: 1 IN 10 YEAR.

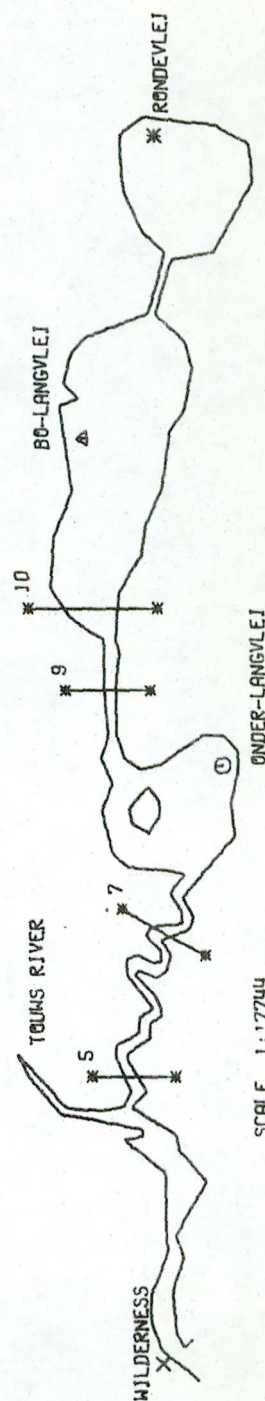
FIGURE
15.2b



MODEL RESULTS. SECTIONS 5+7 DREDGED TO -1.0 M AND
9+10 TO 0.0 M. INITIAL LEVEL : 1.4 M TO MSL.
FLOOD : 1 IN 20 YEAR. MAX DISCHARGE: 170.4 M³/S



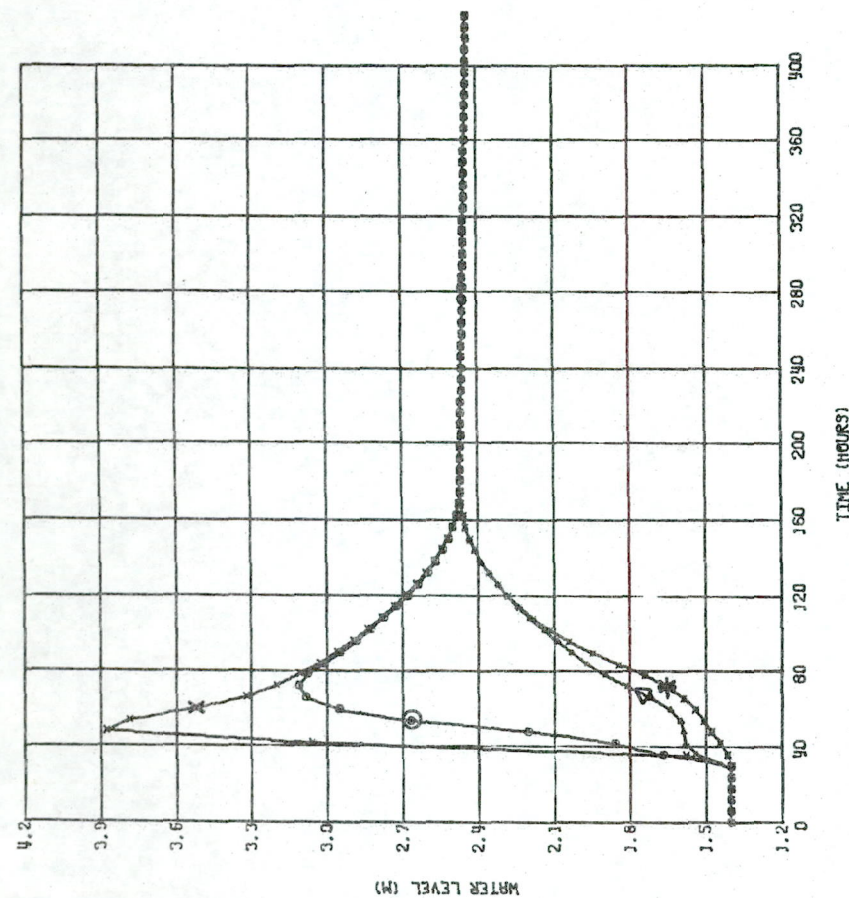
MODEL RESULTS.
ORIGINAL LAYOUT. INITIAL LEVEL : 1.4 M TO MSL.
FLOOD : 1 IN 20 YEAR. MAX DISCHARGE: 170.4 M³/S



TRACED : COMLOT
CHECKED :
: 1980-08-30
C/SEA 8113

WILDERNESS NUMERICAL STUDY
ORIGINAL LAYOUT AND DREDGED SYSTEM.
FLOOD: 1 IN 20 YEAR.

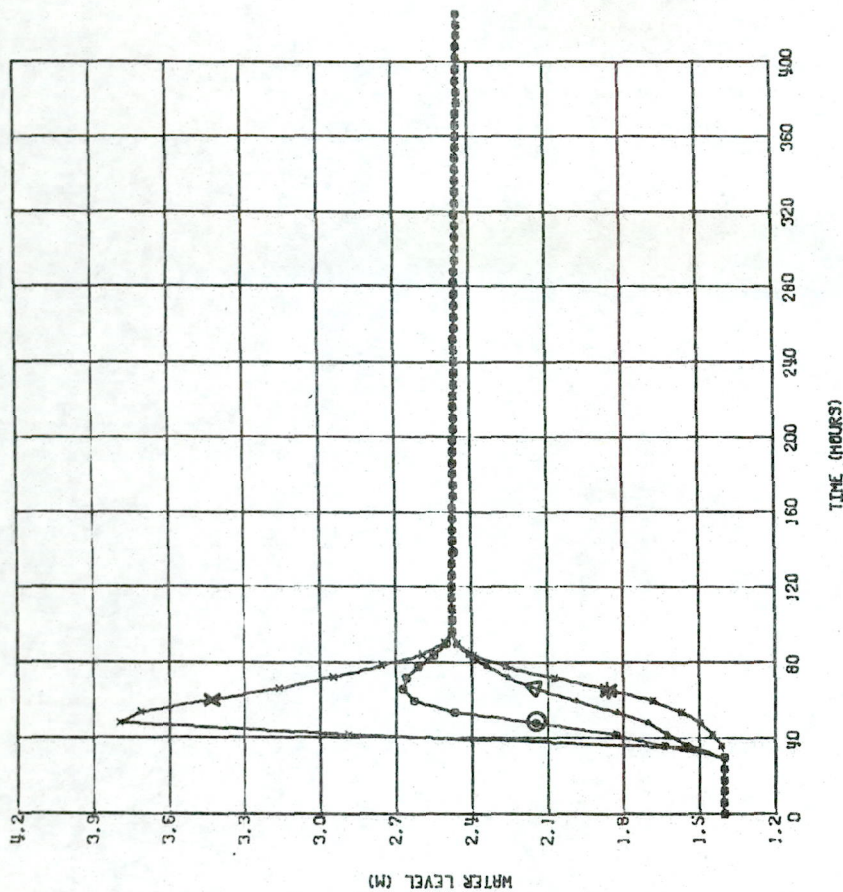
FIGURE
15.2c



MODEL RESULTS.

ORIGINAL LAYOUT, INITIAL LEVEL : 1.4 M TO MSL.

FLOOD : 1 IN 50 YEAR, MAX DISCHARGE: 184.3 M³/S

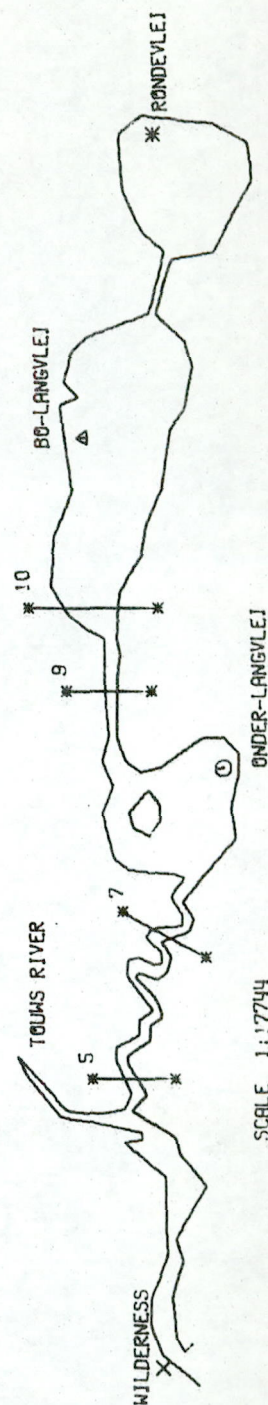


TIME (HOURS)

MODEL RESULTS. SECTIONS 5+7 DREDGED TO -1.0 M AND

9+10 TO 0.0 M. INITIAL LEVEL : 1.4 M TO MSL.

FLOOD : 1 IN 50 YEAR, MAX DISCHARGE: 184.3 M³/S

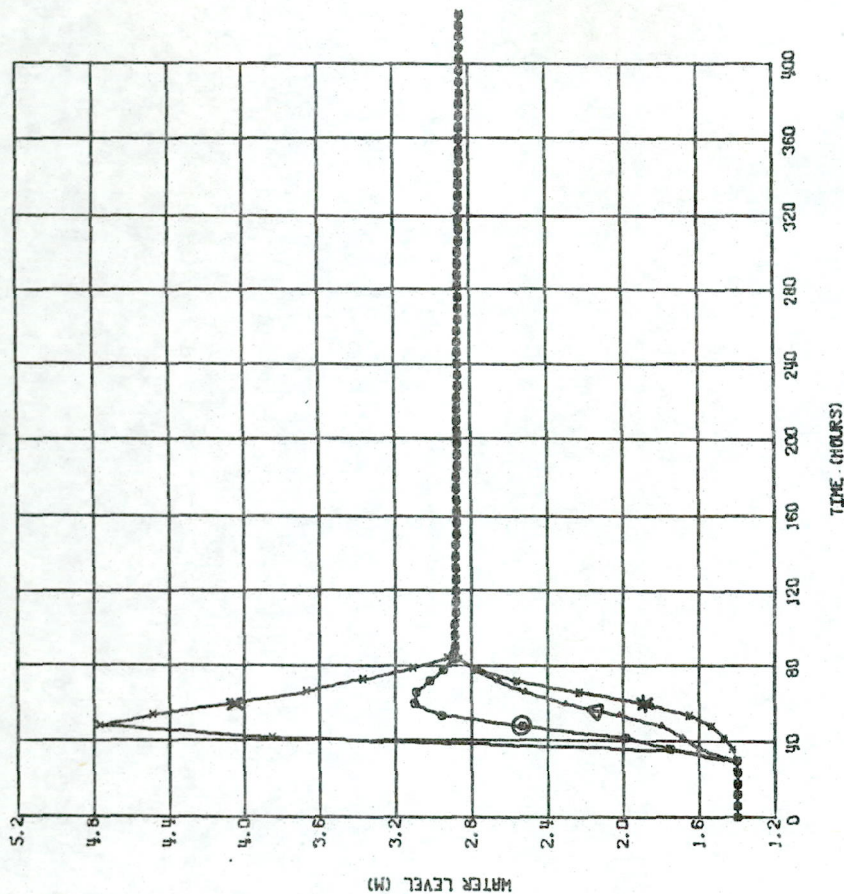


SCALE 1:17744

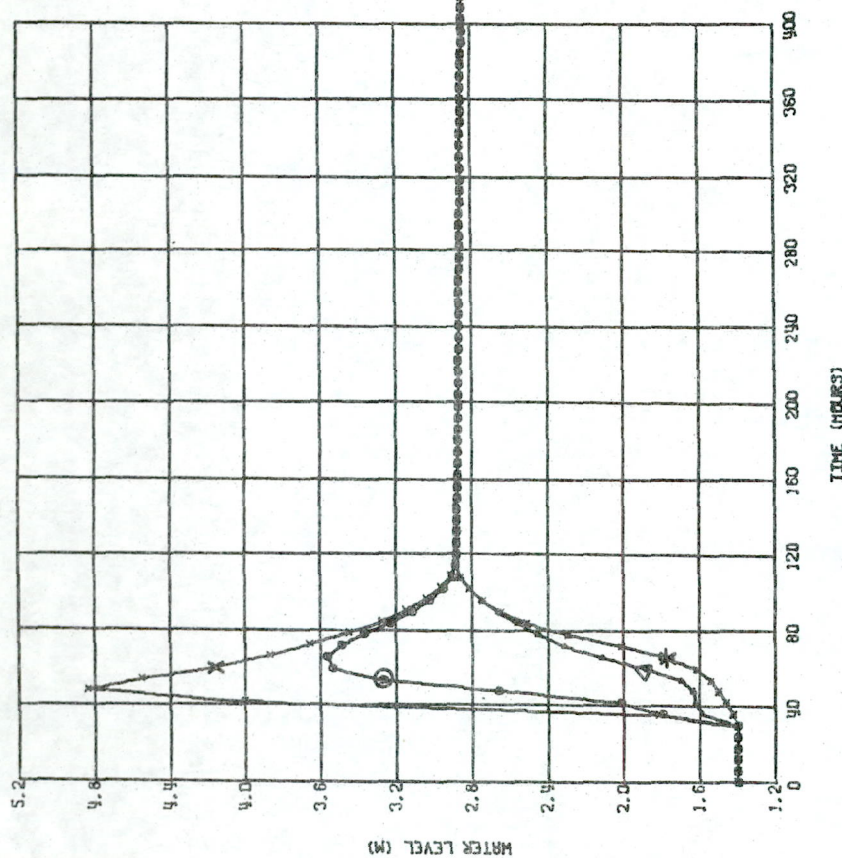
TRACED : COMPLET
CHECKED :
: 1980-08-30
C/SEA 8113

WILDERNESS NUMERICAL STUDY
ORIGINAL LAYOUT AND DREDGED SYSTEM.
FLOOD: 1 IN 50 YEAR.

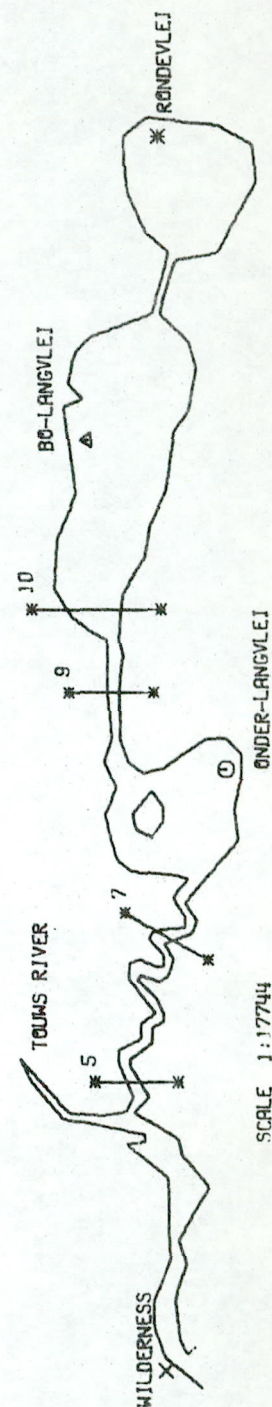
FIGURE
15.2d



MODEL RESULTS. SECTIONS 5 + 7 DREDGED TO -1.0 M AND
SECTIONS 9 + 10 TO 0.0 M. INITIAL LEVEL: 1.4 M TO MSL.
FLOOD: 1 IN 100 YEAR. MAX. DISCHARGE: 278.3 M^3/S .



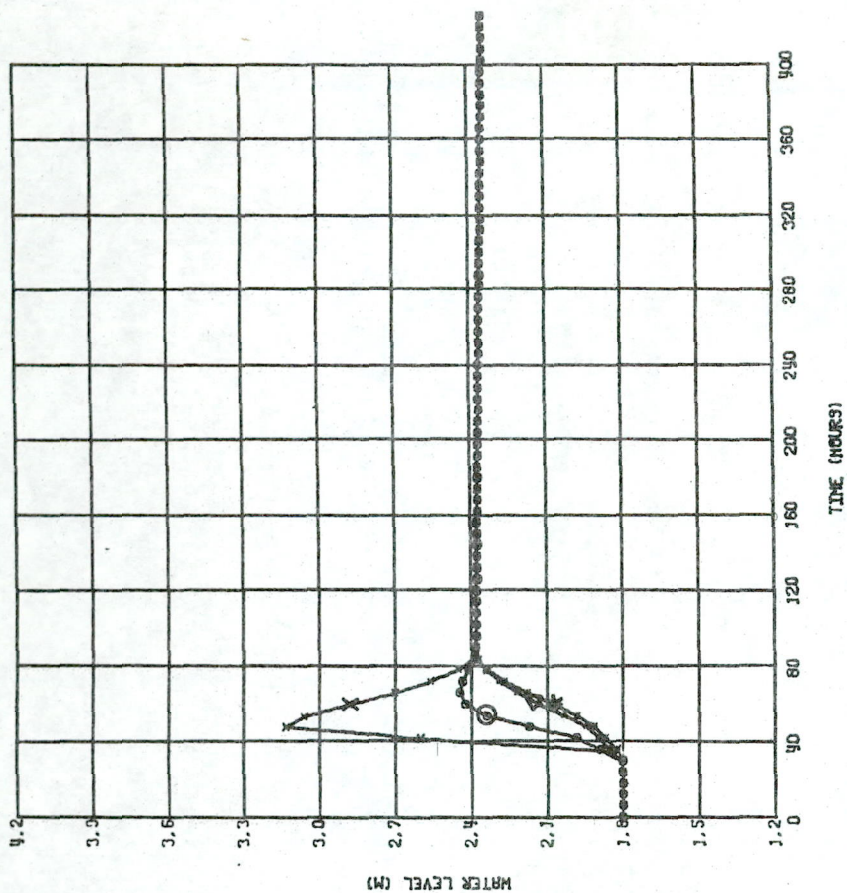
MODEL RESULTS.
ORIGINAL LAYOUT. INITIAL LEVEL: 1.4 M TO MSL.
FLOOD: 1 IN 100 YEAR. MAX. DISCHARGE: 278.3 M^3/S .



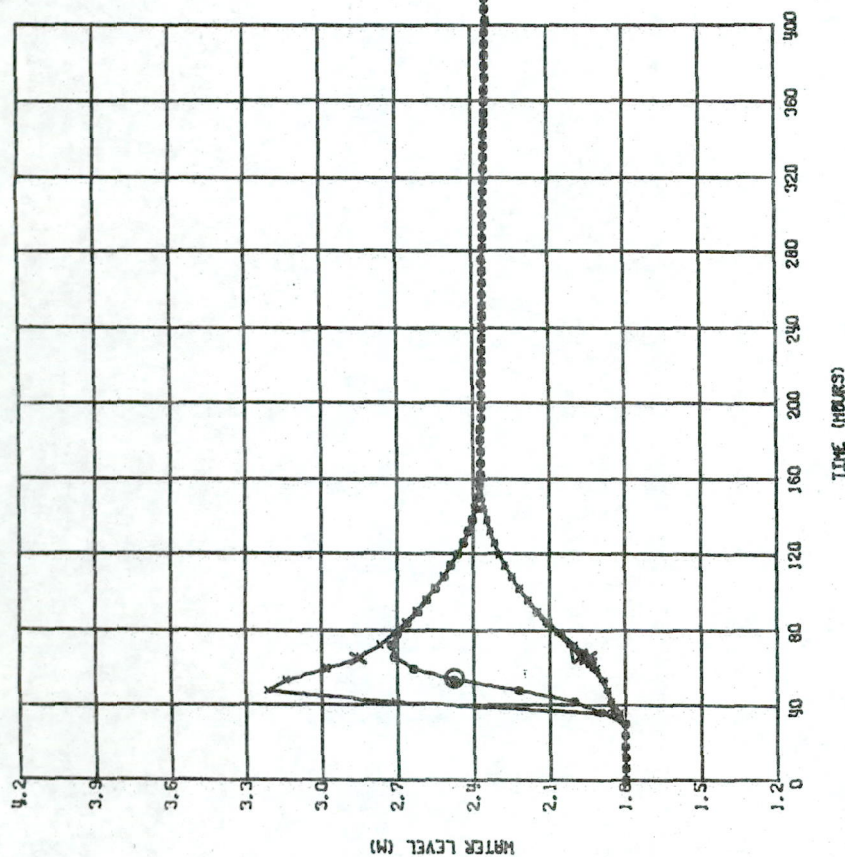
TRACED : COMPILOT
CHECKED :
: 1980-08-30
C/SEA 8113

WILDERNESS NUMERICAL STUDY
ORIGINAL LAYOUT AND DREDGED SYSTEM.
FLOOD: 1 IN 100 YEAR.

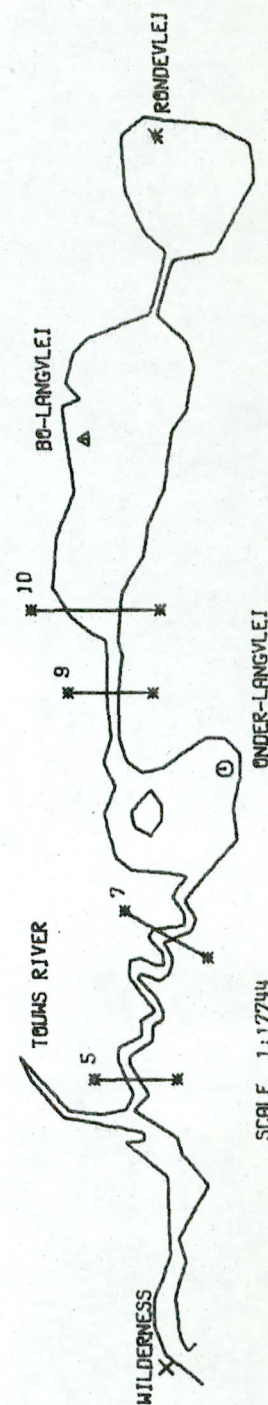
FIGURE
15.2e



MODEL RESULTS. SERPENTINE DREDGED TO -1.0 M TO MSL.
AND LONG CHANNEL TO 0.0 M. INITIAL LEVEL : 1.8 M.
FLOOD: 1 IN 5 YEAR. MAXIMUM DISCHARGE: 109.1 M³/S.



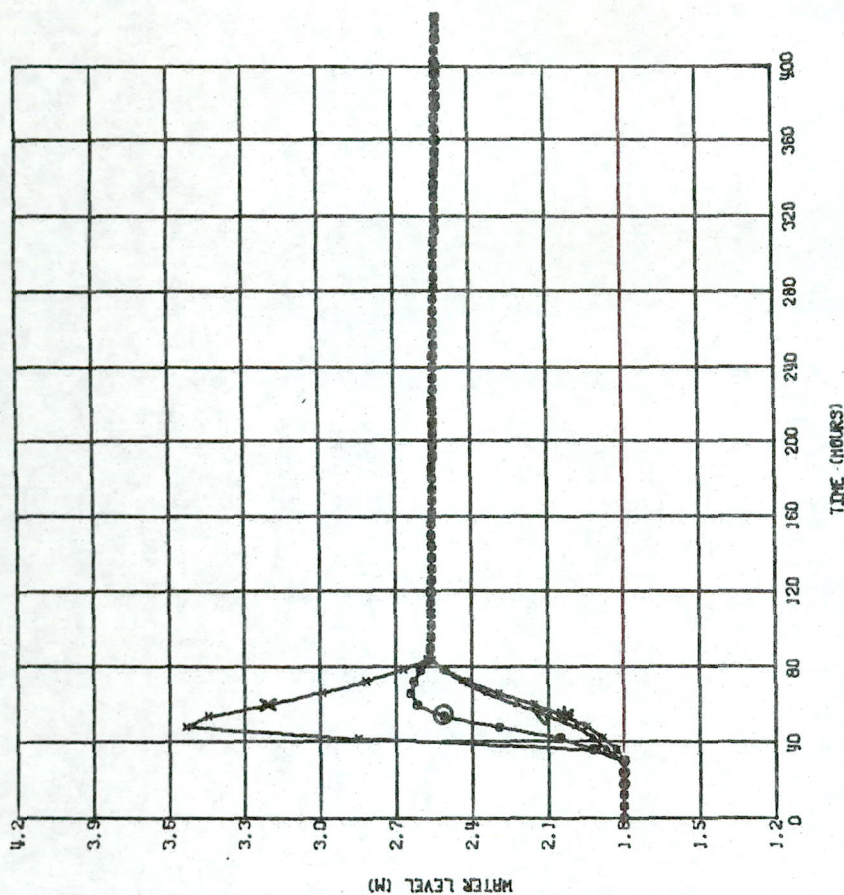
MODEL RESULTS.
ORIGINAL LAYOUT. INITIAL LEVEL : 1.8 M TO MSL.
FLOOD : 1 IN 5 YEAR. MAX. DISCHARGE: 109.1 M³/S.



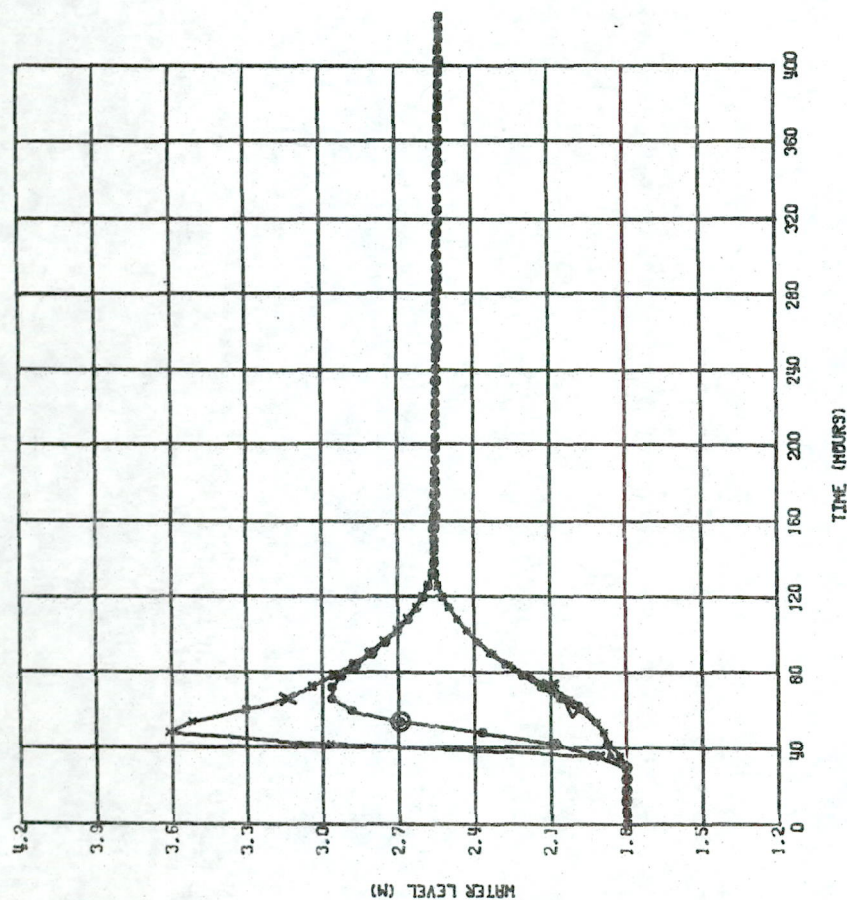
TRACED : COMLOT
CKED :
1980-08-30
C/SEA 8113

WILDERNESS NUMERICAL STUDY
DREDGED SYSTEM.
FLOOD: 1 IN 5 YEAR.

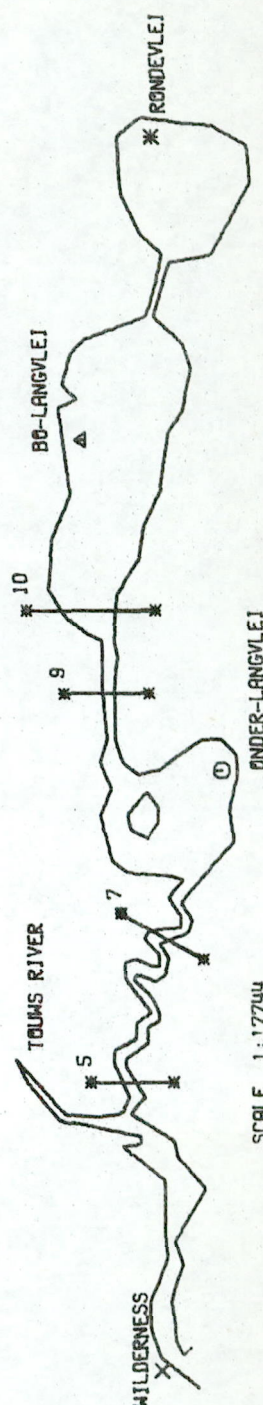
FIGURE
15.3a



MODEL RESULTS. SERPENTINE DREDGED TO -1 M. TO MSL.
AND LONG CHANNEL TO 0 M. INITIAL LEVEL 1.8 M.
FLOOD : 1 IN 10 YEAR. MAX. DISCHARGE: 145.7 M³/S.



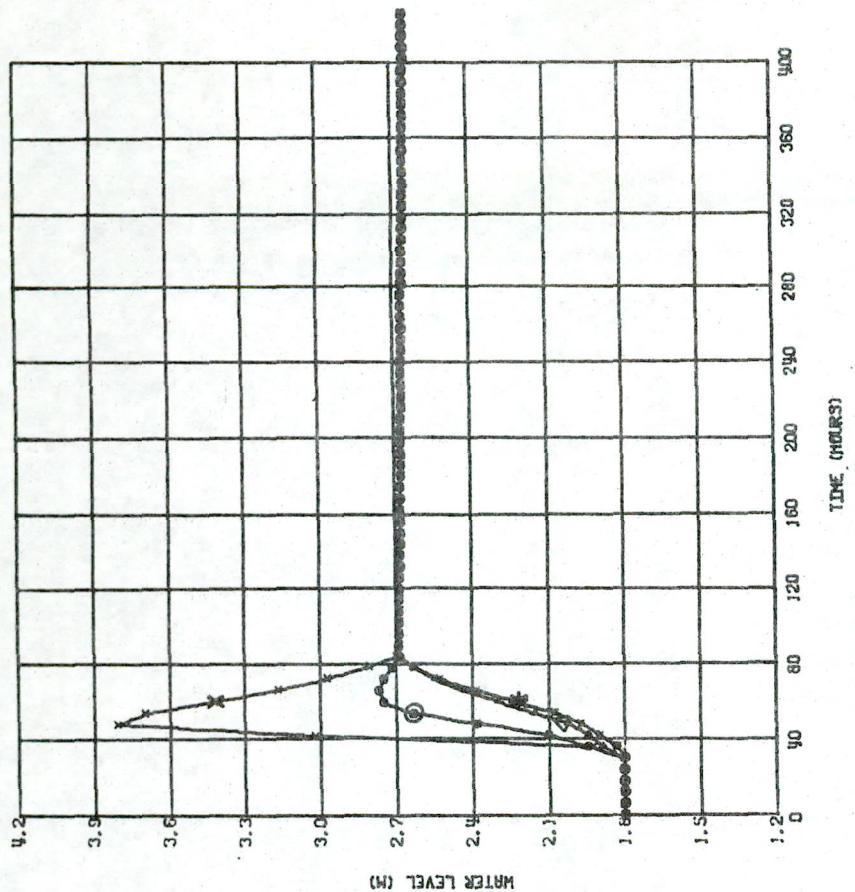
MODEL RESULTS.
ORIGINAL LAYOUT. INITIAL LEVEL : 1.8 M TO MSL.
FLOOD : 1 IN 10 YEAR. MAX. DISCHARGE: 145.7 M³/S.



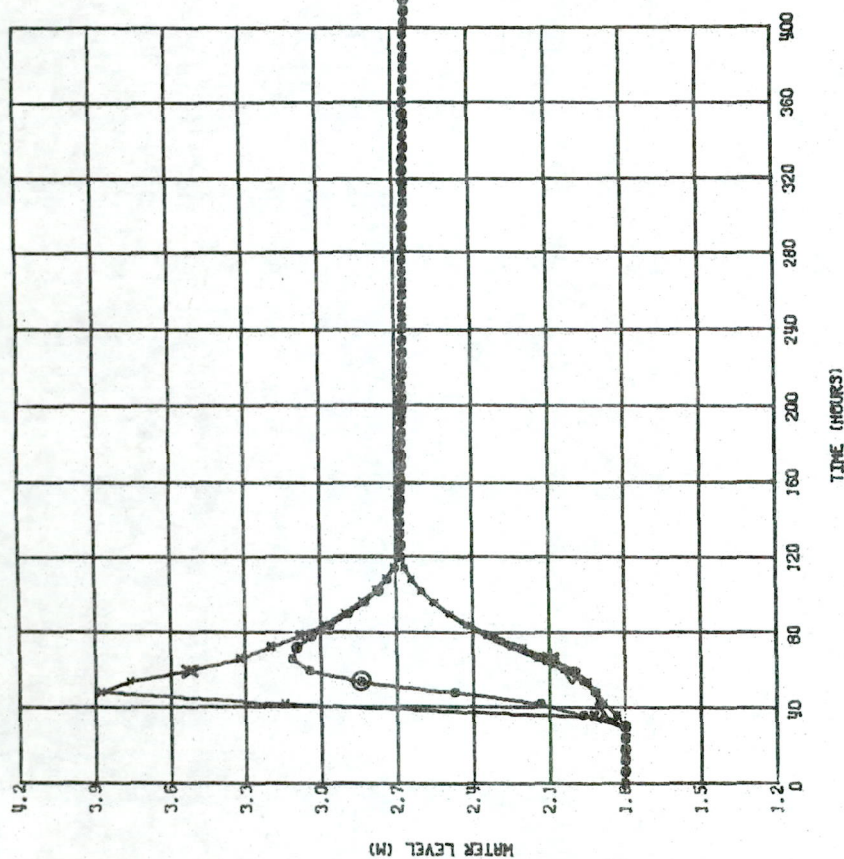
TRACED : COMLOT
CKED :
: 1980-08-30
C/SEA 8113

WILDERNESS NUMERICAL STUDY
DREDGED SYSTEM.
FLOOD: 1 IN 10 YEAR.

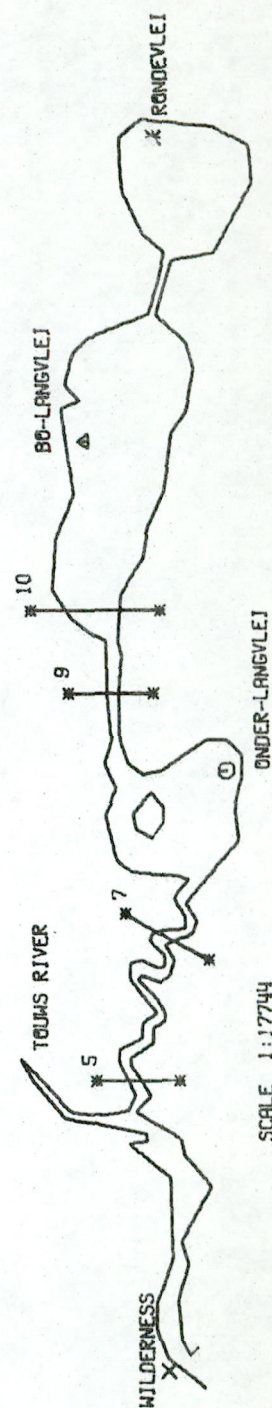
FIGURE
15.3b



MODEL RESULTS. SERPENTINE DREDGED TO -1 M. TO MSL.
AND LONG CHANNEL TO 0 M. INITIAL LEVEL 1.8 M.
FLOOD : 1 IN 20 YEAR. MAX. DISCHARGE: 170.4 M³/S.



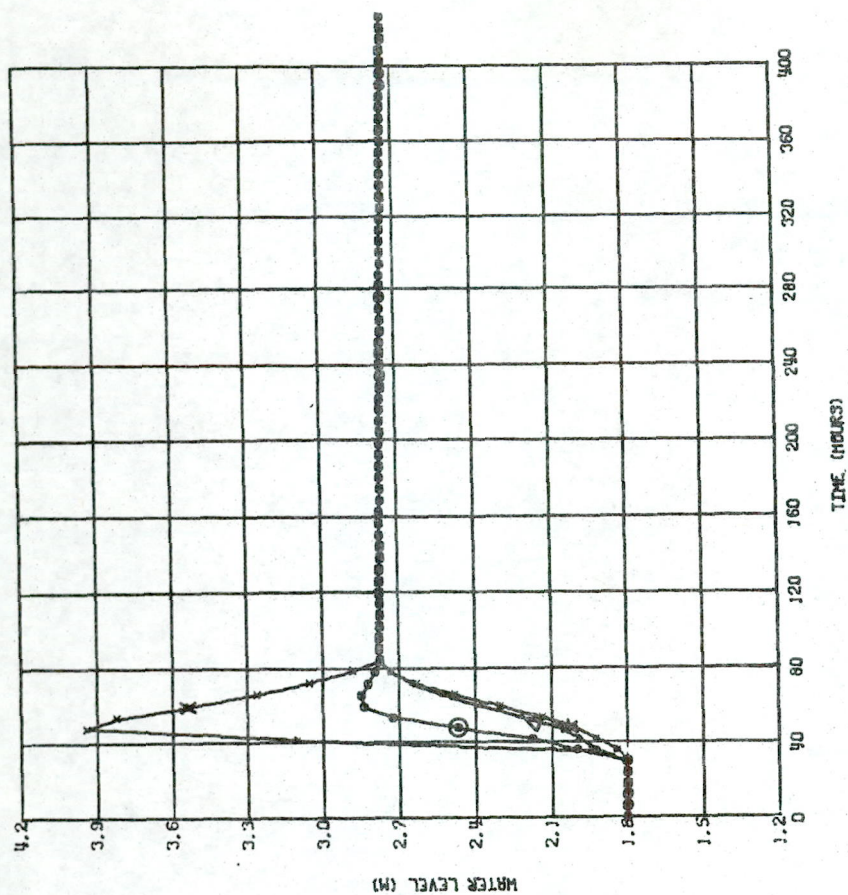
MODEL RESULTS.
ORIGINAL LAYOUT. INITIAL LEVEL : 1.8 M TO MSL.
FLOOD : 1 IN 20 YEAR. MAX. DISCHARGE: 170.4 M³/S.



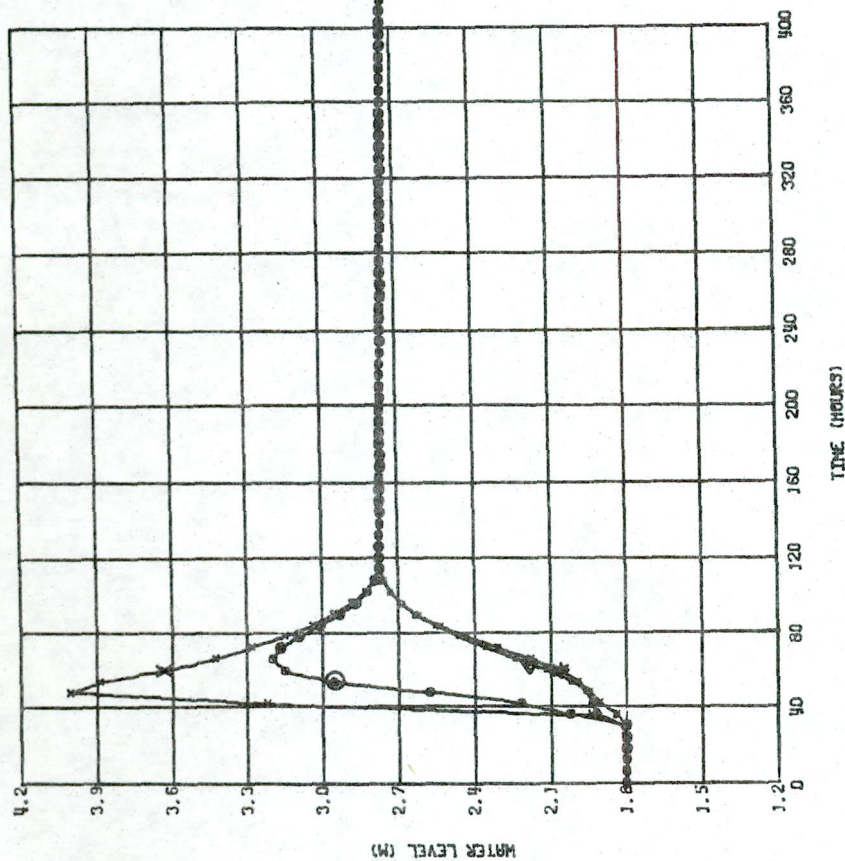
DESIGNED : COMPLET
CHECKED :
1980-08-30
SEA 8113

WILDERNESS NUMERICAL STUDY
DREDGED SYSTEM.
FLOOD: 1 IN 20 YEAR.

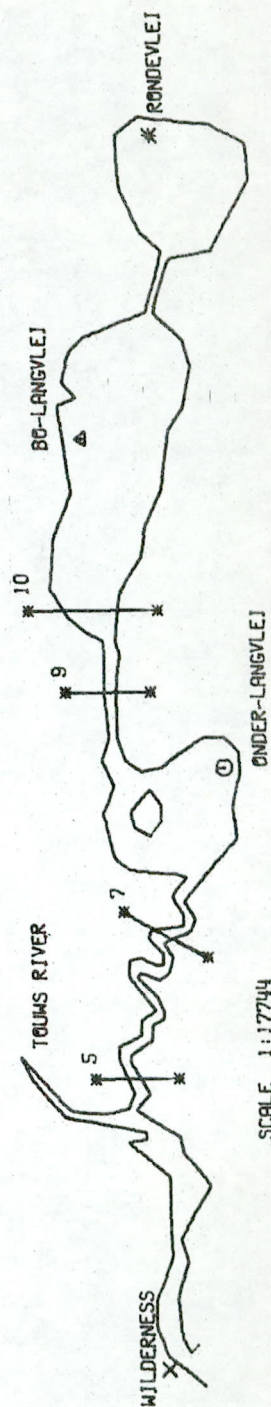
FIGURE
15.3.c



MODEL RESULTS. SERPENTINE DREDGED TO -1 M. TO MSL.
AND LONG CHANNEL TO 0 M. INITIAL LEVEL 1.8 M.
FLOOD : 1 IN 50 YEAR. MAX. DISCHARGE: 184.3 M³/S.



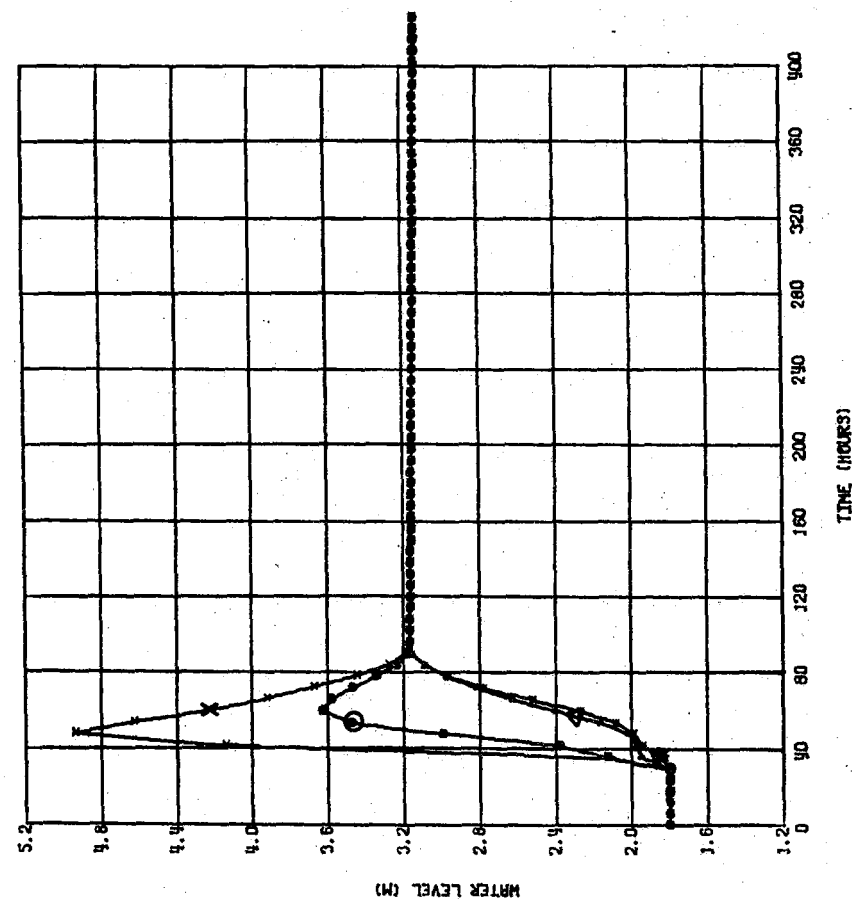
MODEL RESULTS.
ORIGINAL LAYOUT. INITIAL LEVEL : 1.8 M TO MSL.
FLOOD : 1 IN 50 YEAR. MAX. DISCHARGE: 184.3 M³/S.



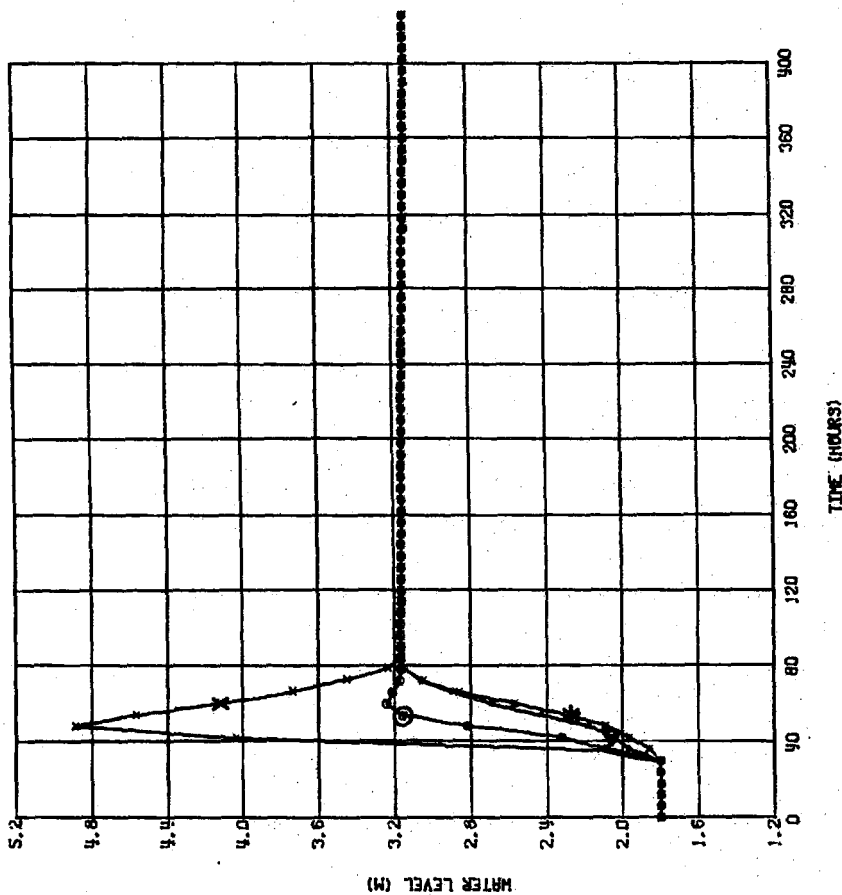
TRACED : COMPILOT
CHECKED :
: 1980-08-30
C/SEA 8113

WILDERNESS NUMERICAL STUDY
DREDGED SYSTEM.
FLOOD: 1 IN 50 YEAR.

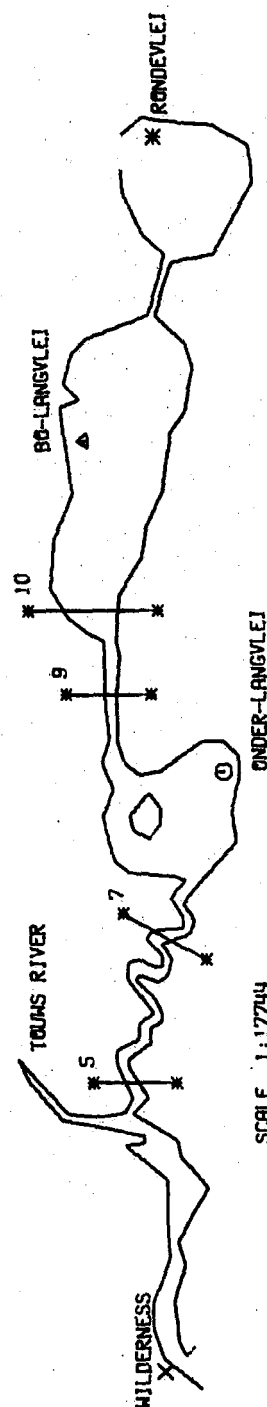
FIGURE
15.3 d



MODEL RESULTS.
ORIGINAL LAYOUT. INITIAL LEVEL : 1.8 M TO MSL.
FLOOD : 1 IN 100 YEAR. MAX. DISCHARGE: 278.3 M³/S.



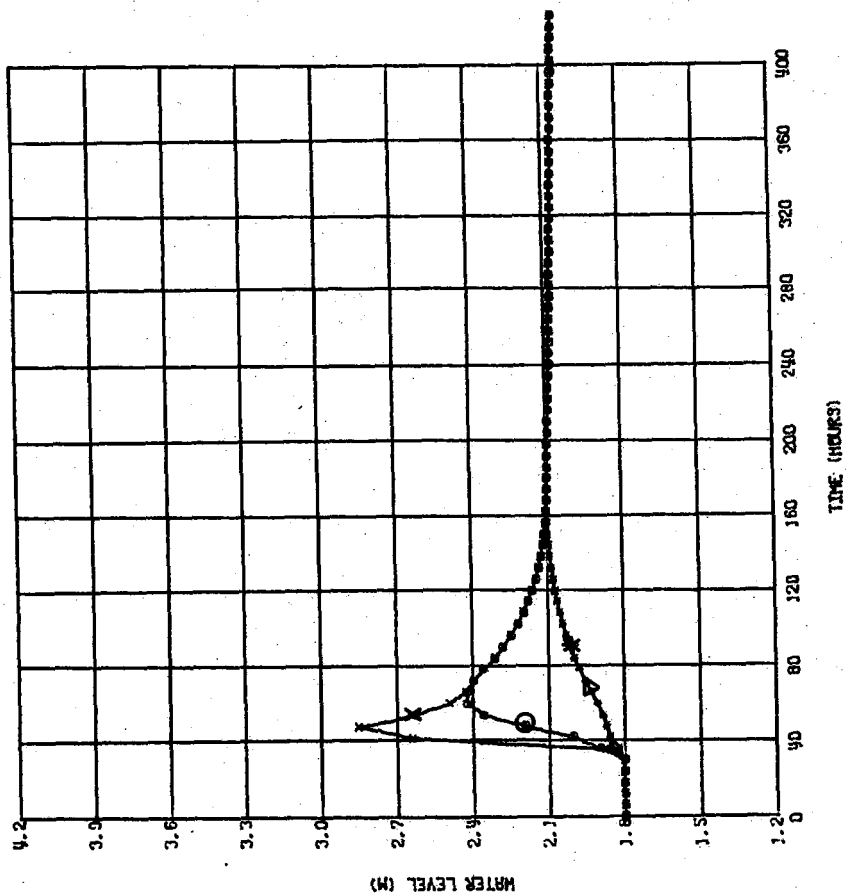
MODEL RESULTS. SECTIONS 5 + 7 DREDGED TO -1.0 M AND
SECTIONS 9 + 10 TO 0.0 M. INITIAL LEVEL: 1.8 M TO MSL.
FLOOD : 1 IN 100 YEAR. MAX. DISCHARGE: 278.3 M³/S.



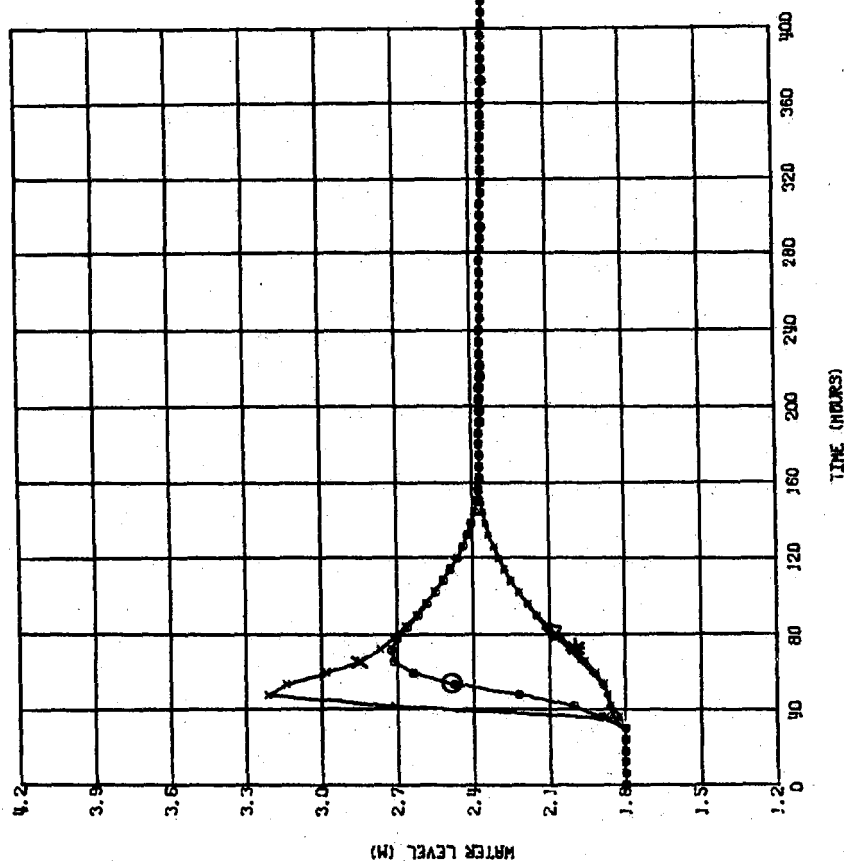
TRACED : COMLOT
CHECKED :
DATE : 1980-08-30
REF. : C/SEA 8/13

WILDERNESS NUMERICAL STUDY
ORIGINAL LAYOUT AND DREDGED SYSTEM.
FLOOD: 1 IN 100 YEAR.

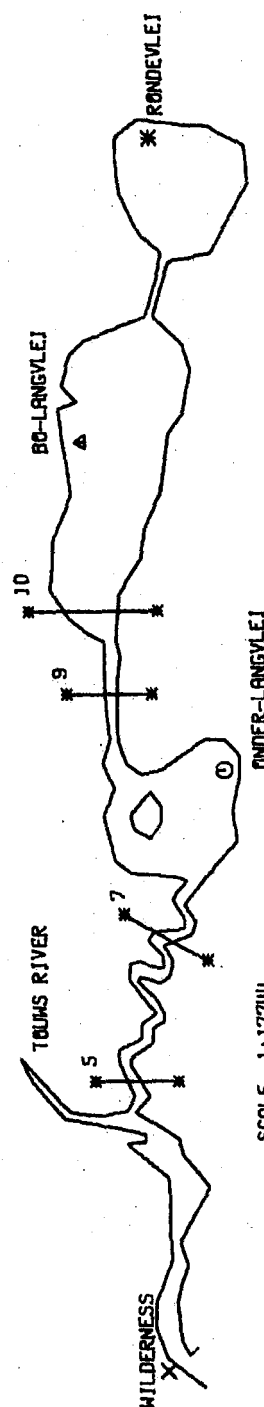
FIGURE
15.3e



MODEL RESULTS. ORIGINAL LAYOUT WITH SILL
(HEIGHT=2 M, WIDTH=30 M, LENGTH=20 M) INITIAL LEVEL: 1.8 M.
FLOOD: 1 IN 5 YEAR. MAX. DISCHARGE: 109.1 M³/S.



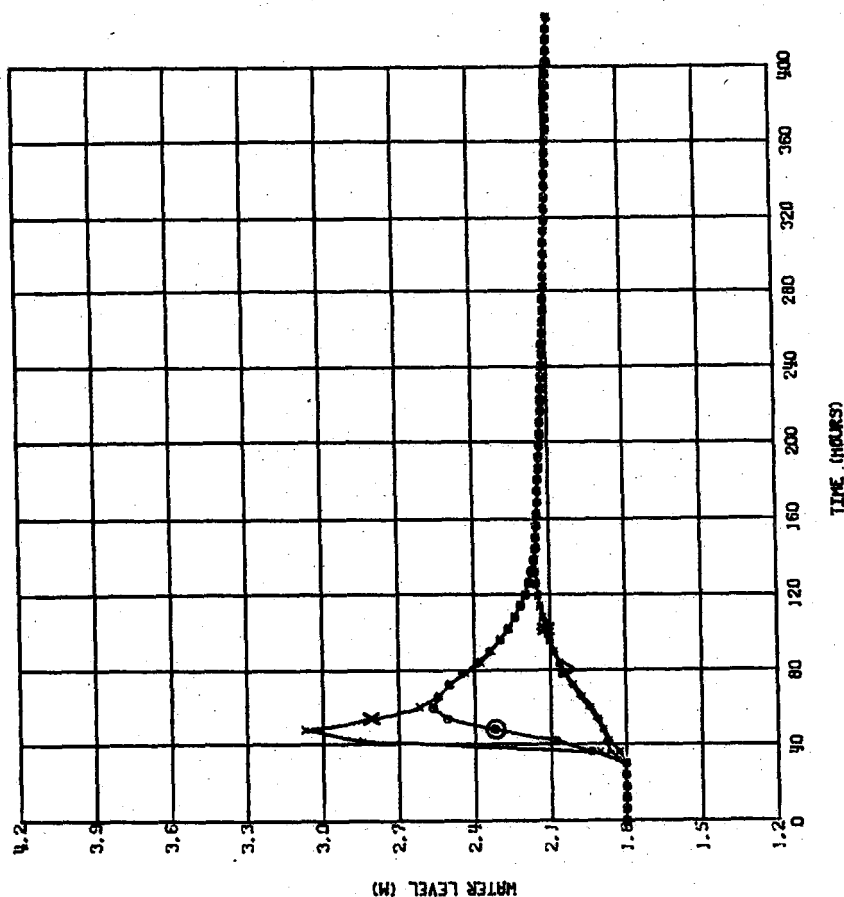
MODEL RESULTS.
ORIGINAL LAYOUT. INITIAL LEVEL : 1.8 M TO MSL.
FLOOD : 1 IN 5 YEAR. MAX. DISCHARGE: 109.1 M³/S.



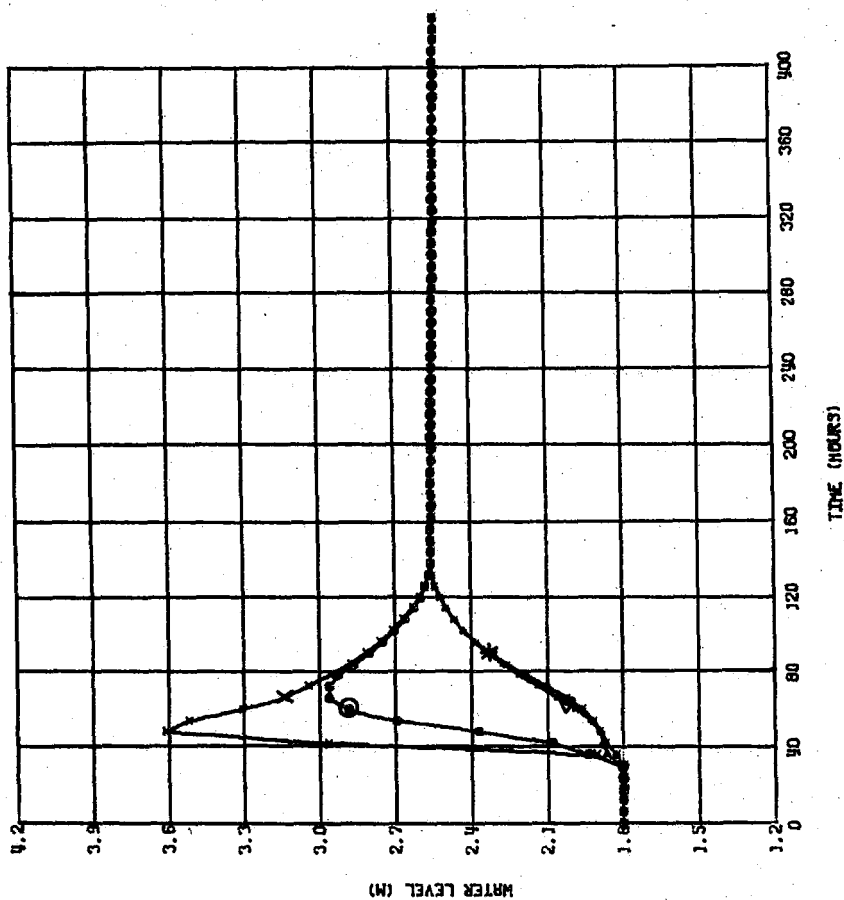
TRACED : COMPLIT
CHECKED :
DATE : 1980-08-30
REF. : C/SEA 8/113

WILDERNESS NUMERICAL STUDY
ORIGINAL LAYOUT WITH SILL (H=2 M,
B=30 M, L=20 M) FLOOD: 1 IN 5 YEAR.

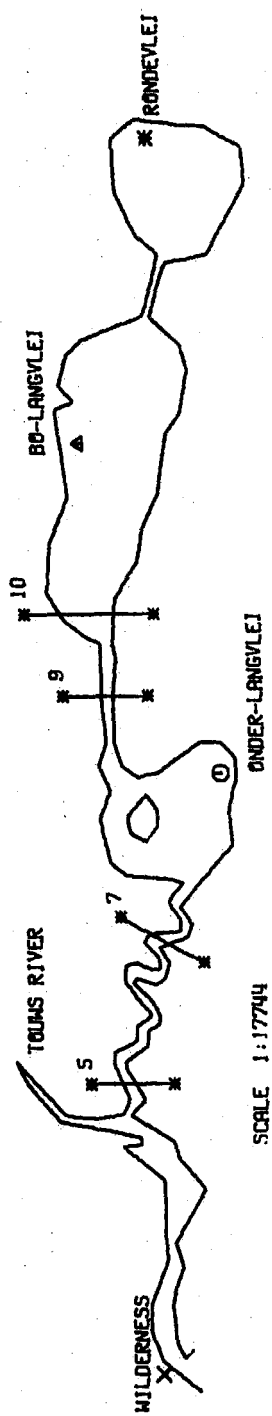
FIGURE
16a



MODEL RESULTS. ORIGINAL LAYOUT WITH SILL
 (HEIGHT=2 M, WIDTH=30 M, LENGTH=20 M) INITIAL LEVEL: 1.8 M.
 FLOOD: 1 IN 10 YEAR. MAX. DISCHARGE: 145.7 M³/S.



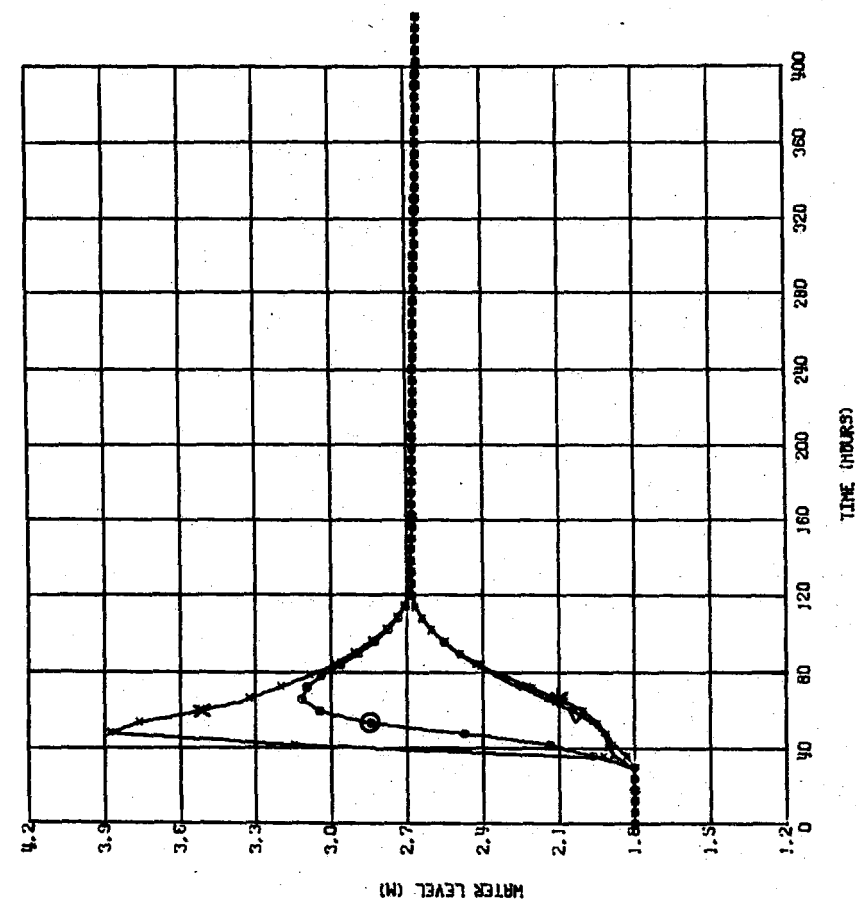
MODEL RESULTS.
 ORIGINAL LAYOUT. INITIAL LEVEL: 1.8 M TO MSL.
 FLOOD: 1 IN 10 YEAR. MAX. DISCHARGE: 145.7 M³/S.



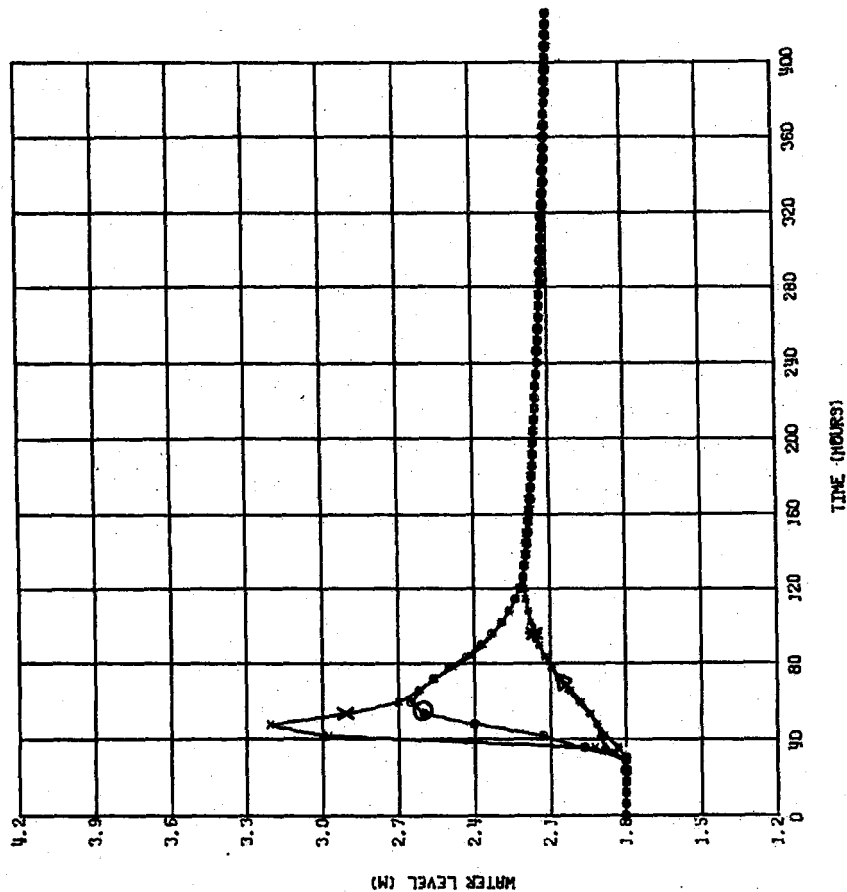
TRACED : COMLOT
 CHECKED :
 DATE : 1980-08-30
 REF. : C/SEA 8113

WILDERNESS NUMERICAL STUDY
 ORIGINAL LAYOUT WITH SILL (H=2 M,
 B=30 M, L=20 M) FLOOD: 1 IN 10 YEAR.

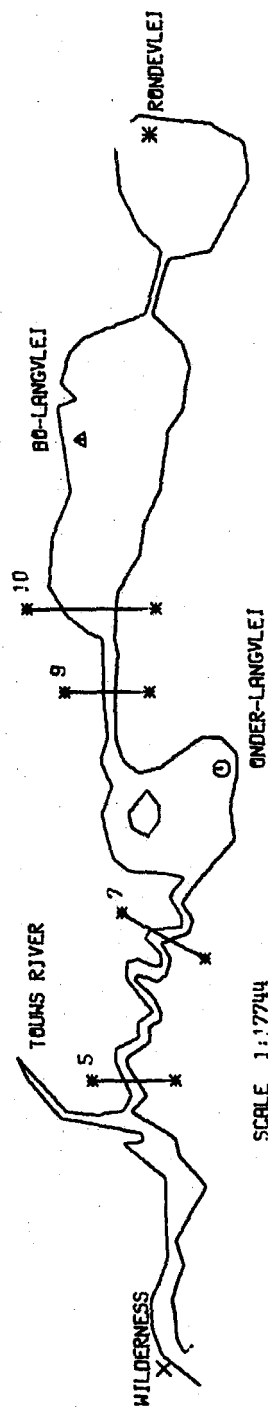
FIGURE
 16 b



MODEL RESULTS.
ORIGINAL LAYOUT. INITIAL LEVEL : 1.8 M TO MSL.
FLOOD : 1 IN 20 YEAR. MAX. DISCHARGE: 170.4 M³/S.



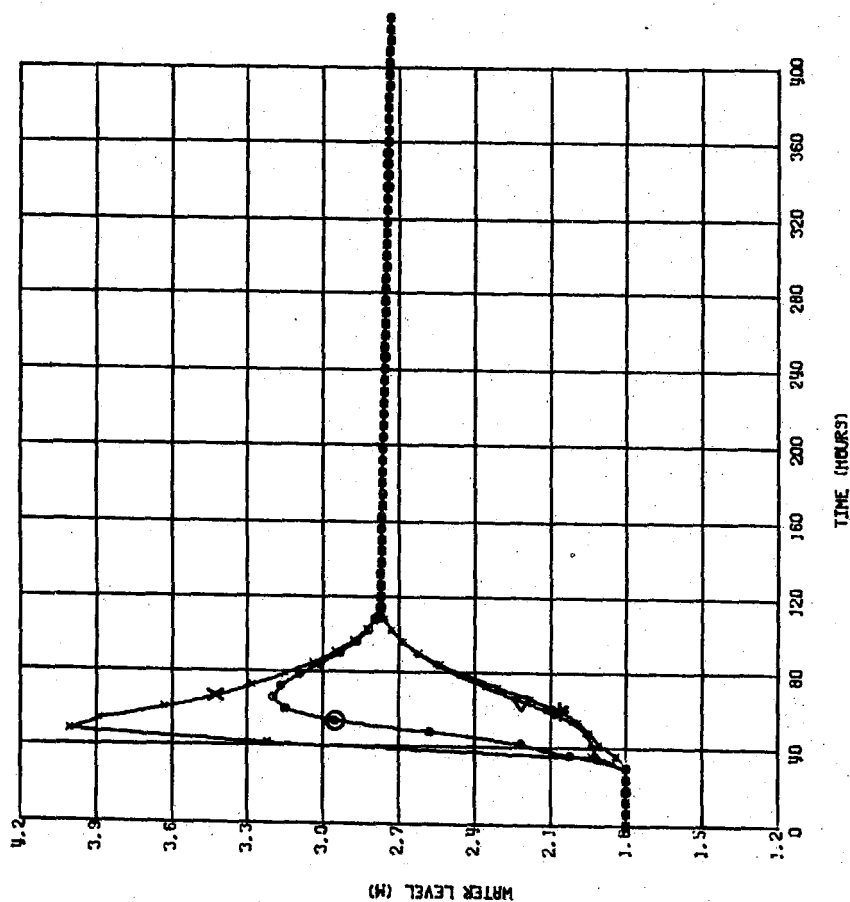
MODEL RESULTS. ORIGINAL LAYOUT WITH SILL
(HEIGHT=2 M, WIDTH=30 M, LENGTH=20 M) INITIAL LEVEL: 1.8 M.
FLOOD : 1 IN 20 YEAR. MAX. DISCHARGE: 170.4 M³/S.



TRACED : COMPLIT
CHECKED :
DATE : 1980-08-30
REF. : C/SEA 8113

WILDERNESS NUMERICAL STUDY
ORIGINAL LAYOUT WITH SILL (H=2 M,
B=30 M, L=20 M) FLOOD: 1 IN 20 YEAR.

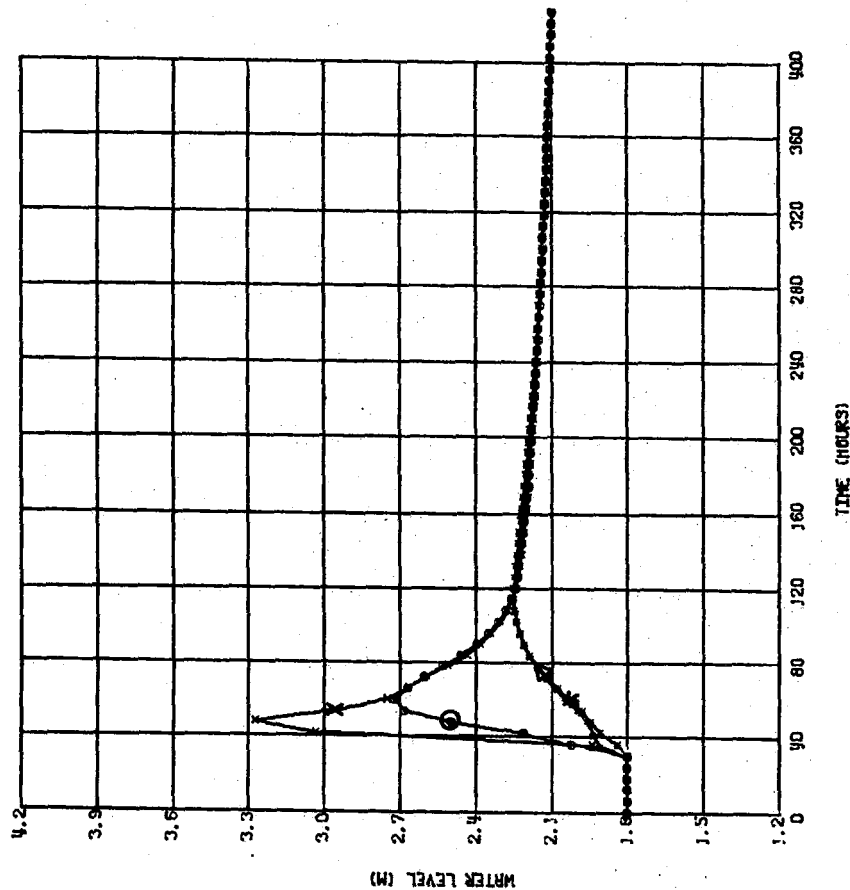
FIGURE
16c



MODEL RESULTS.

ORIGINAL LAYOUT. INITIAL LEVEL : 1.8 M TO MSL.

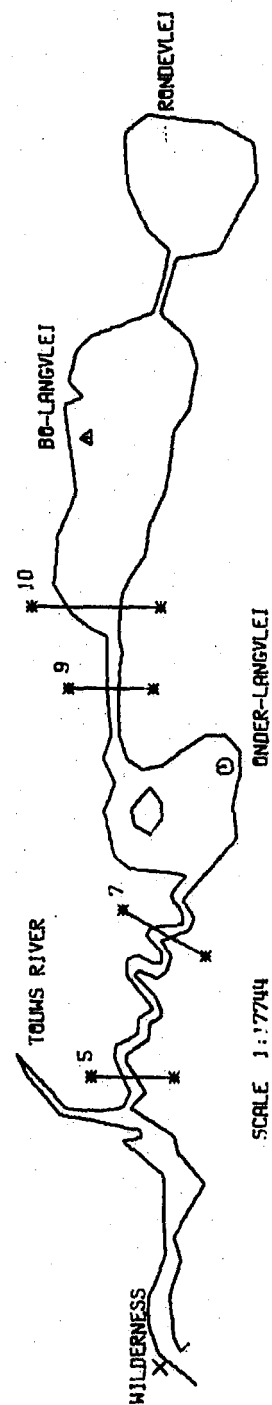
FLOOD : 1 IN 50 YEAR. MAX. DISCHARGE: 184.3 M^3/S .



MODEL RESULTS. ORIGINAL LAYOUT WITH SILL

(HEIGHT=2 M, WIDTH=30 M, LENGTH=20 M) INITIAL LEVEL: 1.8 M.

FLOOD: 1 IN 50 YEAR. MAX. DISCHARGE: 184.3 M^3/S .

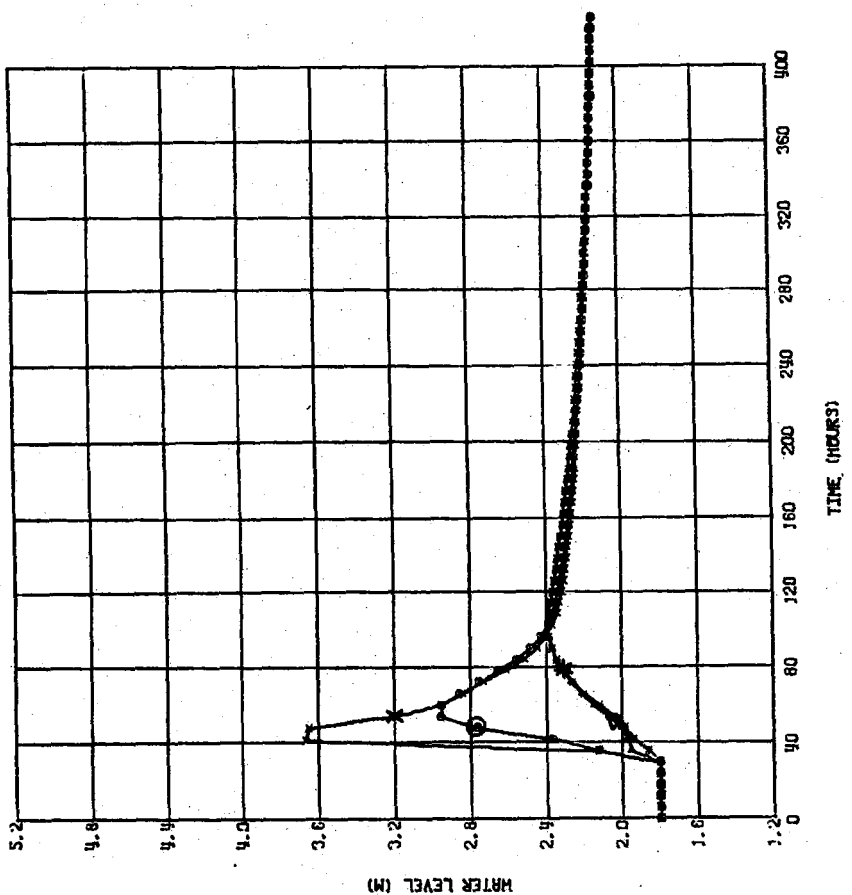


TRACED : COMPT
CHECKED :
DATE : 1980-08-30
REF. : C/SEA 8113

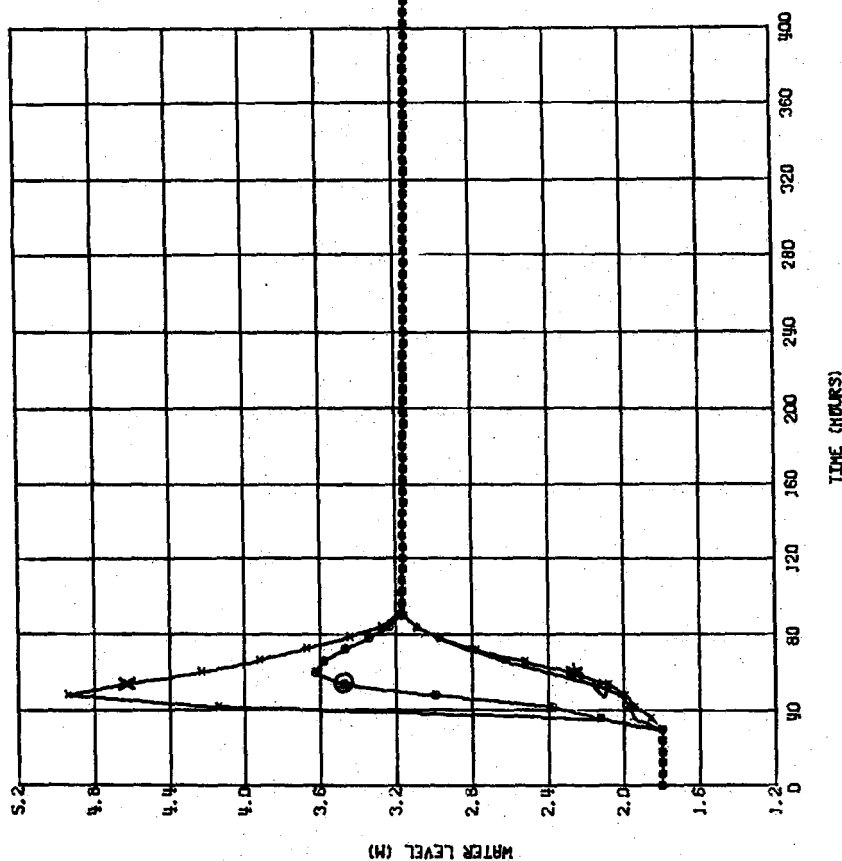
WILDERNESS NUMERICAL STUDY
ORIGINAL LAYOUT WITH SILL (H=2 M,
B=30 M, L=20 M) FLOOD: 1 IN 50 YEAR.

FIGURE
16d

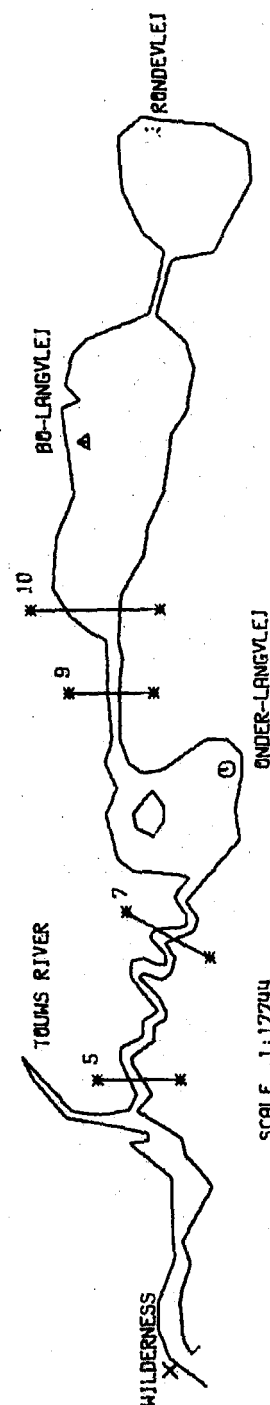
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MODEL RESULTS. ORIGINAL LAYOUT WITH SILL.
 (HEIGHT=2 M, WIDTH=30 M, LENGTH=20 M) INITIAL LEVEL: 1.8 M TO MSL.
 FLOOD: 1 IN 100 YEAR. MAX. DISCHARGE: 278.3 M³/S.



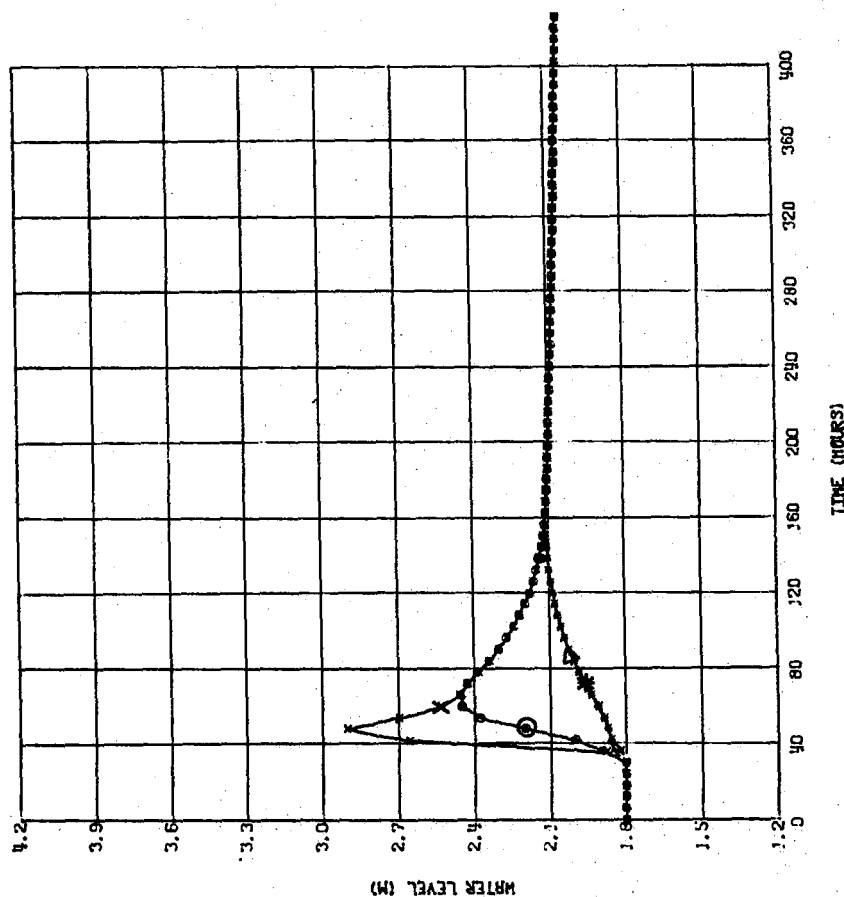
MODEL RESULTS.
 ORIGINAL LAYOUT. INITIAL LEVEL: 1.8 M TO MSL.
 FLOOD: 1 IN 100 YEAR. MAX. DISCHARGE: 278.3 M³/S.



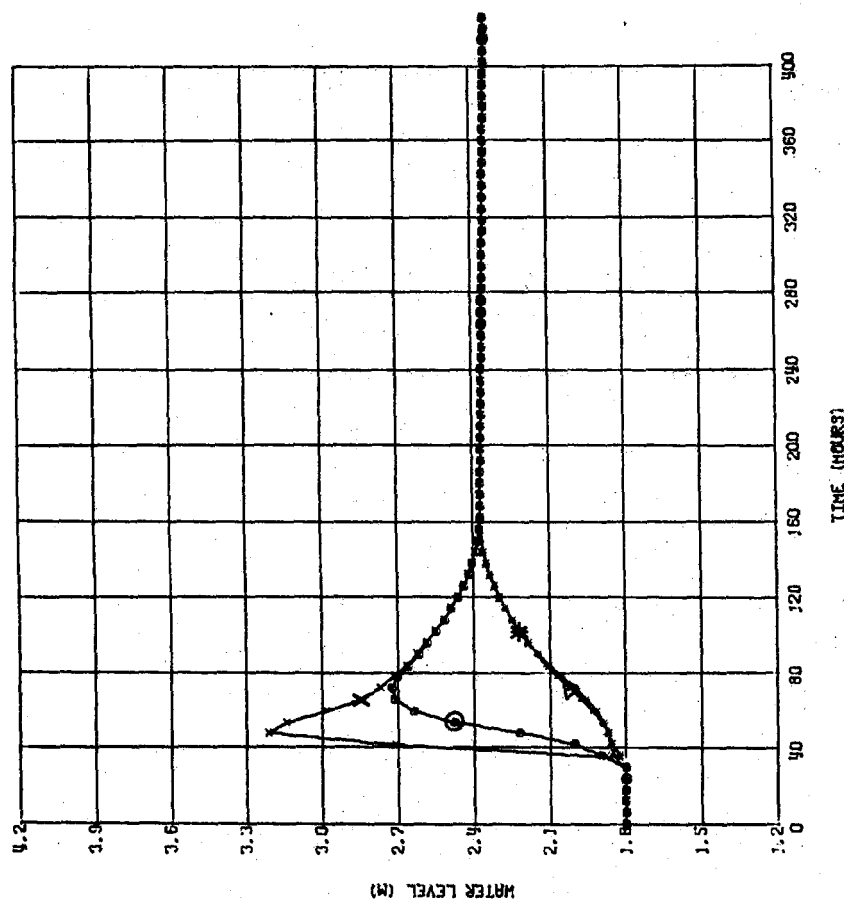
TRACED : COMPILOT
 CHECKED :
 DATE : 1980-08-30
 REF. : C/SEA 8/13

WILDERNESS NUMERICAL STUDY
 ORIGINAL LAYOUT WITH SILL (H=2 M,
 B=30 M, L=20 M) FLOOD: 1 IN 100 YEAR.

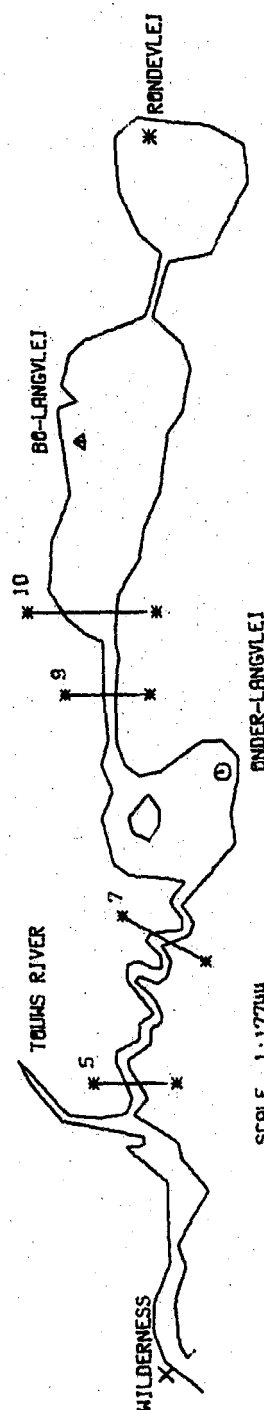
FIGURE
 16e



ORIGINAL LAYOUT WITH SILL SCOURING TO 1.0 M.
 (HEIGHT=2M, WIDTH=40M, LENGTH=120M) INITIAL LEVEL: 1.8 M.
 FLOOD: 1 IN 5 YEAR. MAXIMUM DISCHARGE: 109.1 M³/S.



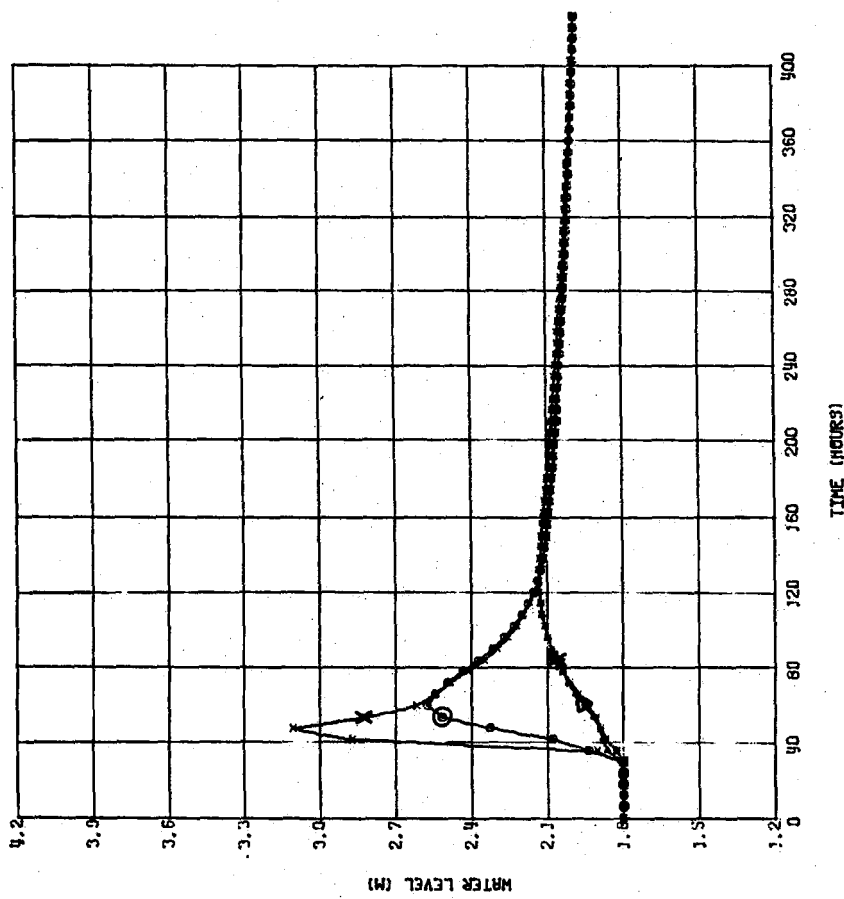
ORIGINAL LAYOUT. INITIAL LEVEL: 1.8 M. TO MSL.
 FLOOD: 1 IN 5 YEAR. MAXIMUM DISCHARGE: 109.1 M³/S



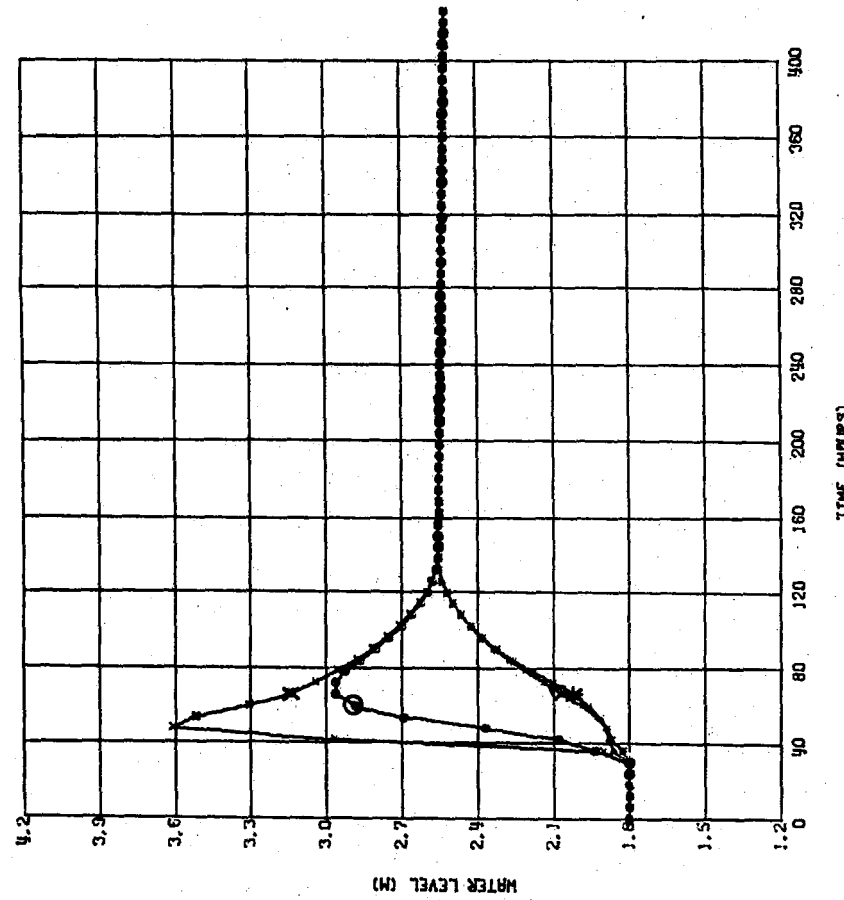
TRACED : COMPILOT
 CHECKED :
 DATE : 1980-08-30
 REF. : C/SEA 2113

WILDERNESS NUMERICAL STUDY
 ORIGINAL LAYOUT WITH SCOURING SILL (H=2,
 B=40M, L=120M) FLOOD: 1 IN 5 YEAR.

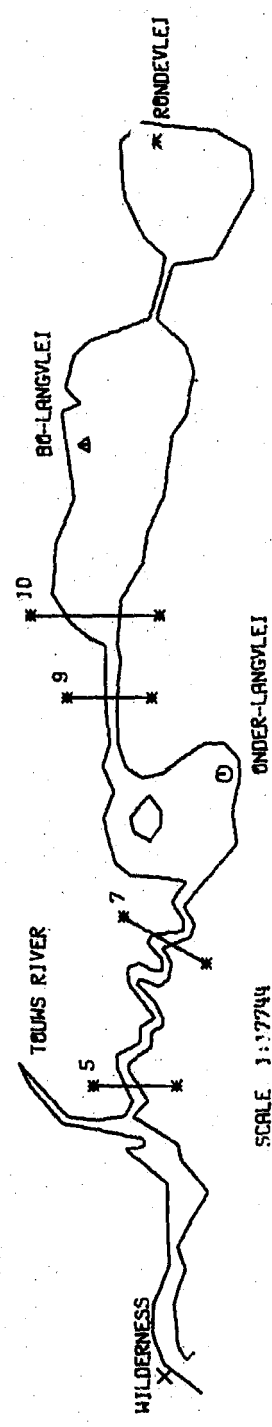
FIGURE
 17.1a

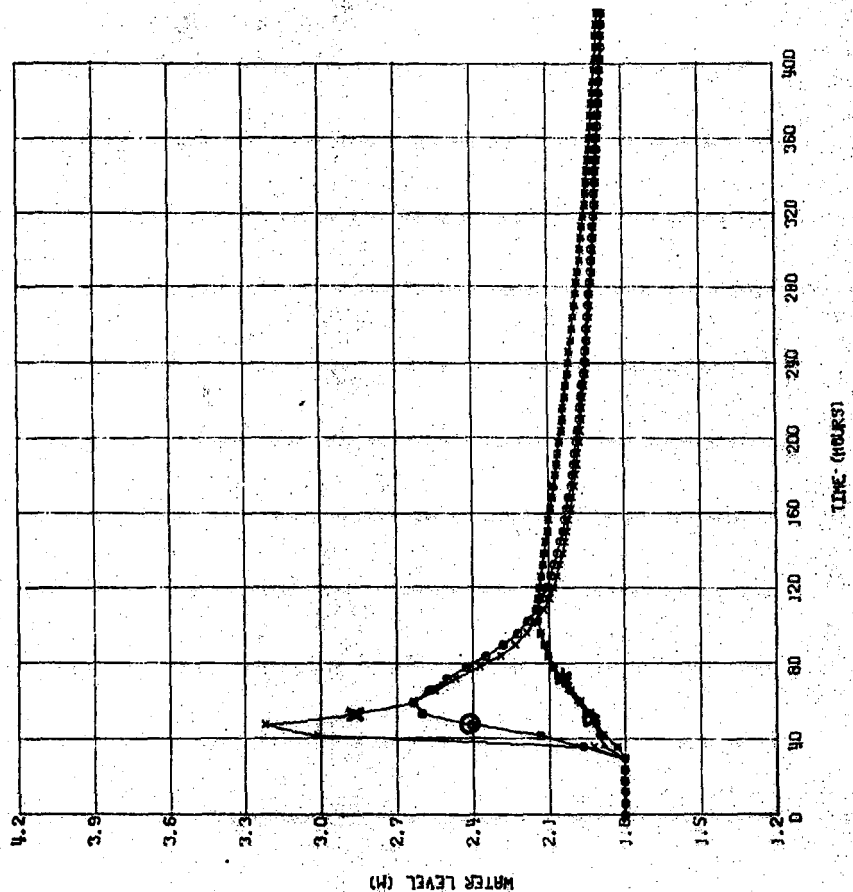


ORIGINAL LAYOUT WITH SILL SCOURING TO 1.0 M.
 (HEIGHT=2M, WIDTH=40M, LENGTH=120M) INITIAL LEVEL: 1.8 M.
 FLOOD: 1 IN 10 YEAR. MAXIMUM DISCHARGE: 145.7 M³/S.

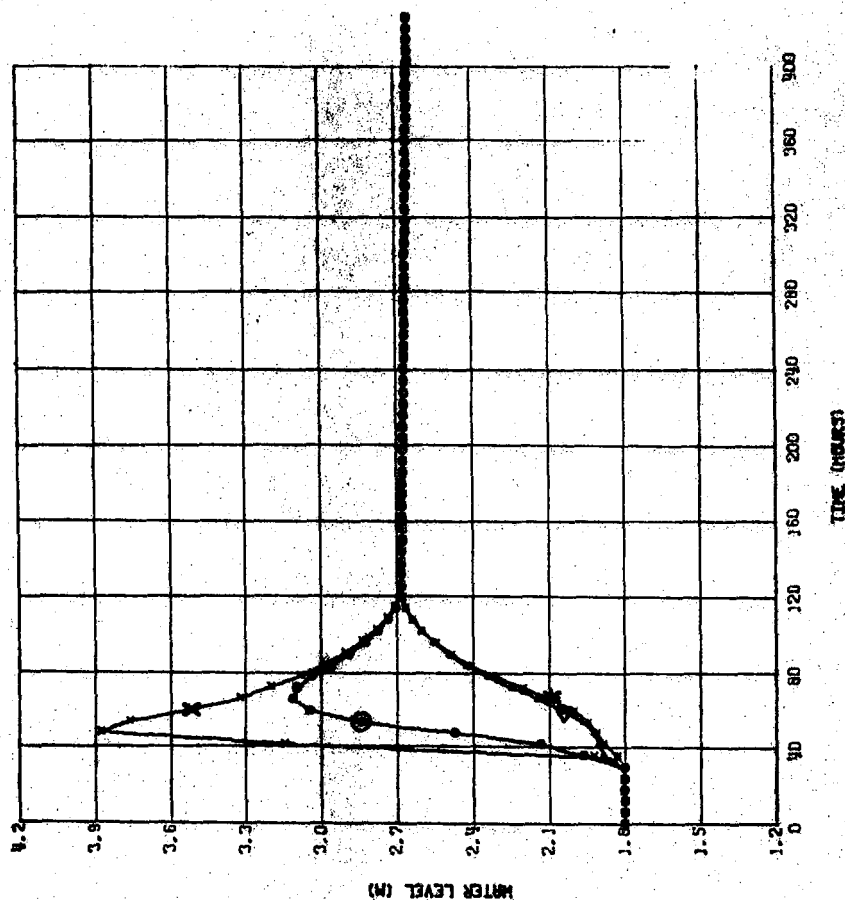


ORIGINAL LAYOUT. INITIAL LEVEL: 1.8 M. TO MSL.
 FLOOD: 1 IN 10 YEAR. MAXIMUM DISCHARGE: 145.7 M³/S

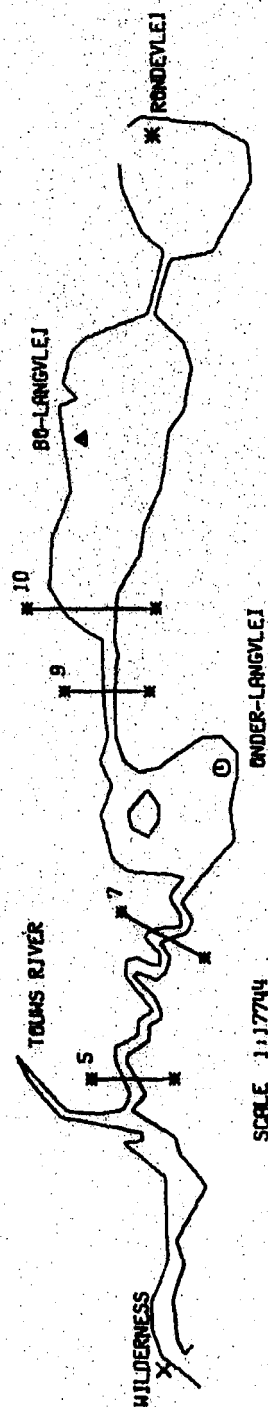




ORIGINAL LAYOUT WITH SILL SCOURING TO 1.0 M.
 (HEIGHT=2M, WIDTH=40M, LENGTH=120M) INITIAL LEVEL: 1.8 M.
 FLOOD: 1 IN 20 YEAR, MAXIMUM DISCHARGE: 170.4 M³/S.



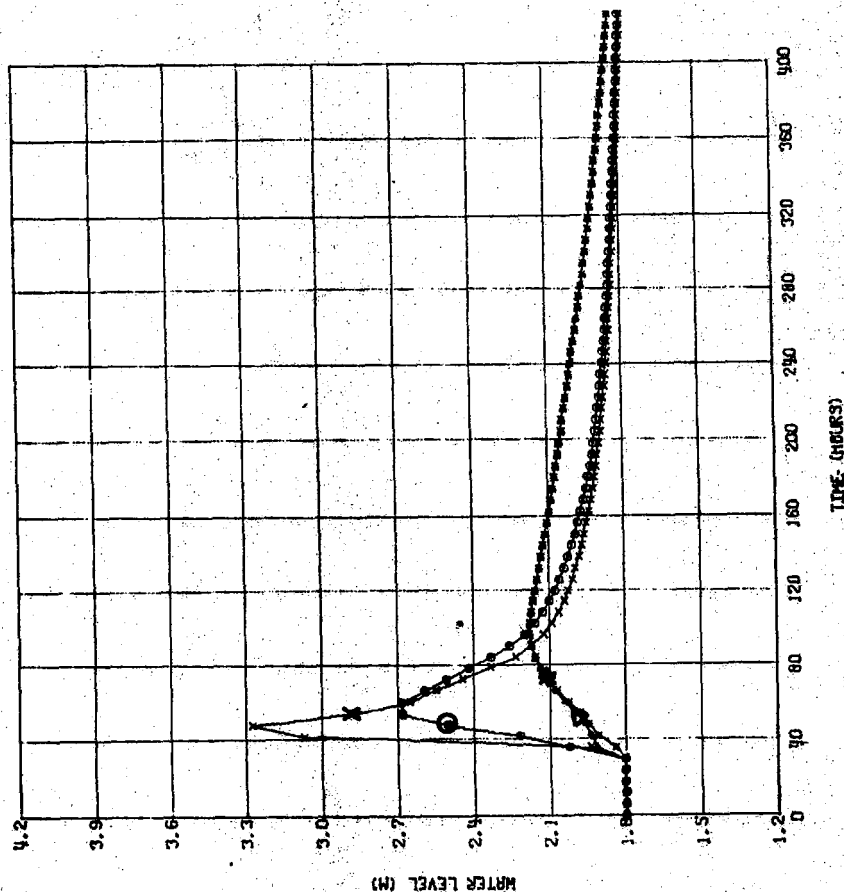
ORIGINAL LAYOUT, INITIAL LEVEL: 1.8 M. TO MSL.
 FLOOD: 1 IN 20 YEAR, MAXIMUM DISCHARGE: 170.4 M³/S.



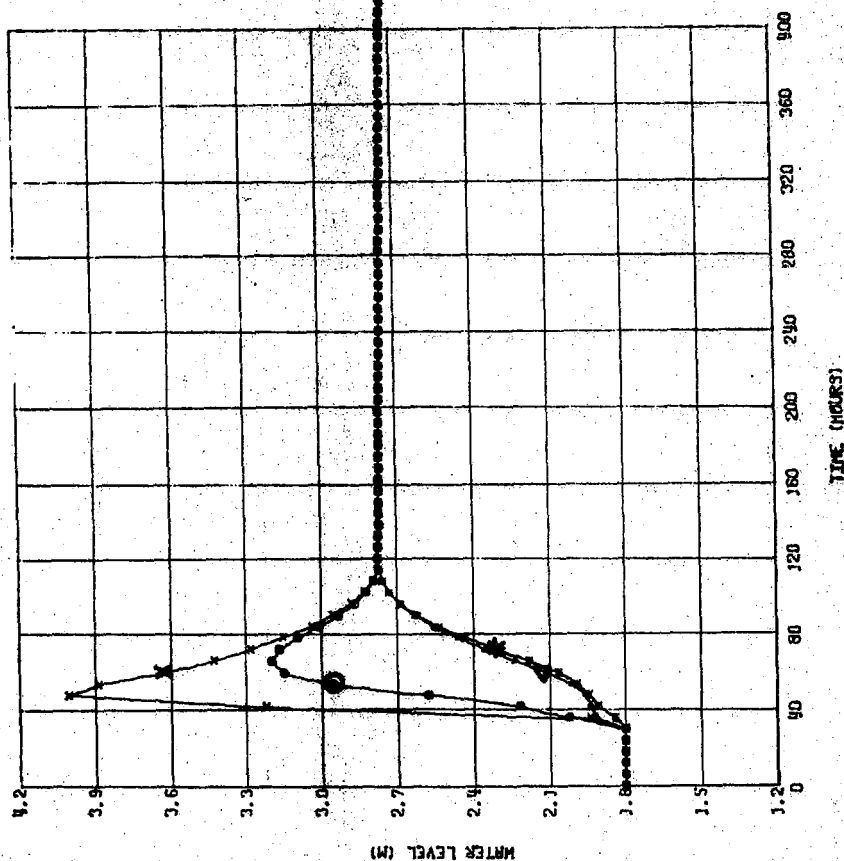
TRACED : COMPILOT
 CHECKED :
 DATE : 1980-08-30
 REF. : C/SEA 8/13

WILDERNESS NUMERICAL STUDY
 ORIGINAL LAYOUT WITH SCOURING SILL (H=2,
 B=40M, L=120M) FLOOD: 1 IN 20 YEAR.

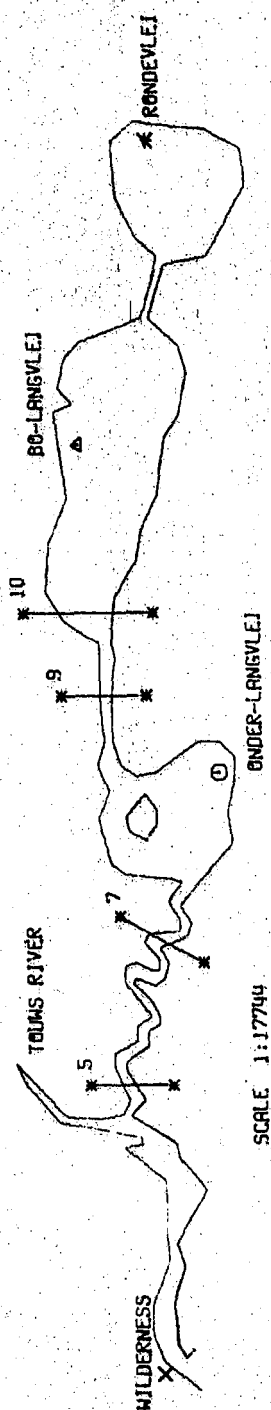
FIGURE
 17.1c



ORIGINAL LAYOUT WITH SILL SCOURING TO 1.0 M.
(HEIGHT=2M, WIDTH=40M, LENGTH=120M) INITIAL LEVEL: 1.8 M.
FLOOD: 1 IN 50 YEAR, MAXIMUM DISCHARGE: 183.1 M³/S.



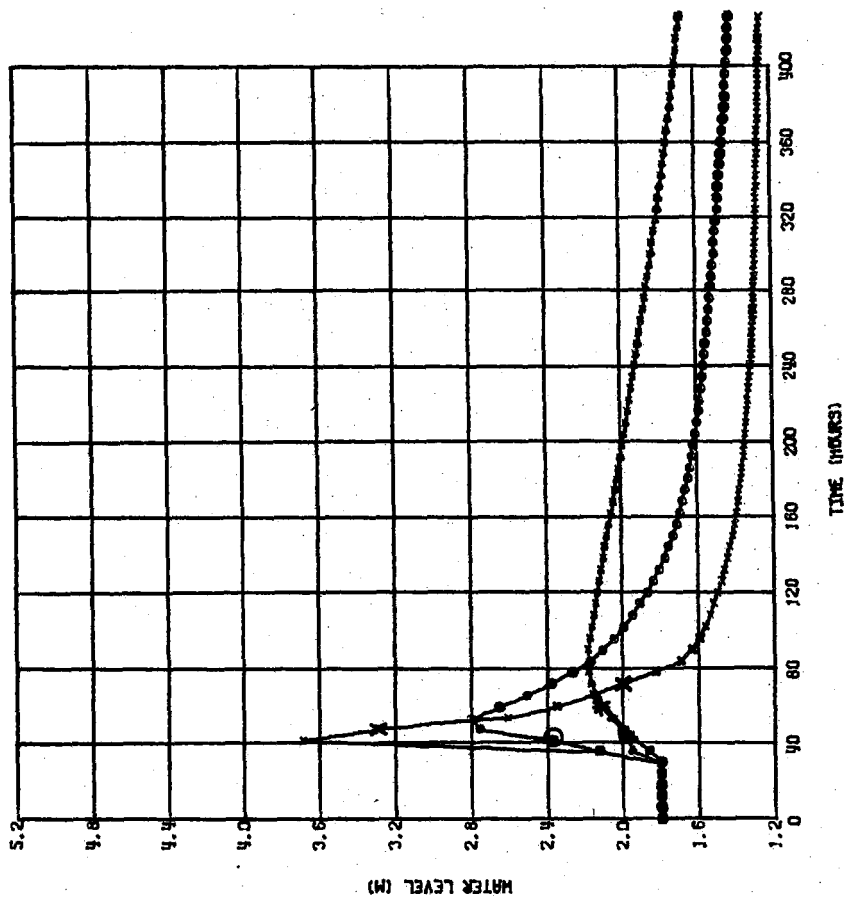
ORIGINAL LAYOUT. INITIAL LEVEL: 1.8 M. TO MSL.
FLOOD: 1 IN 50 YEAR, MAXIMUM DISCHARGE: 183.1 M³/S.



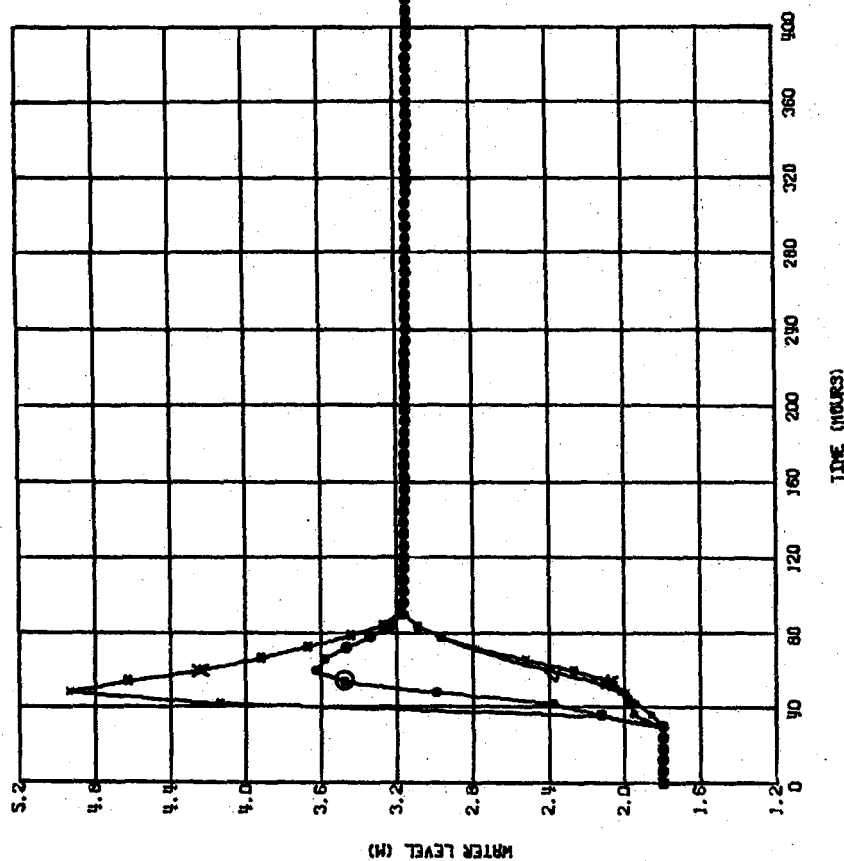
TRACED : COMPLT
CHECKED :
DATE : 1980-08-30
REF. : C/SEA 8113

WILDERNESS NUMERICAL STUDY
ORIGINAL LAYOUT WITH SCOURING SILL (H=2,
B=40M, L=120M) FLOOD: 1 IN 50 YEAR.

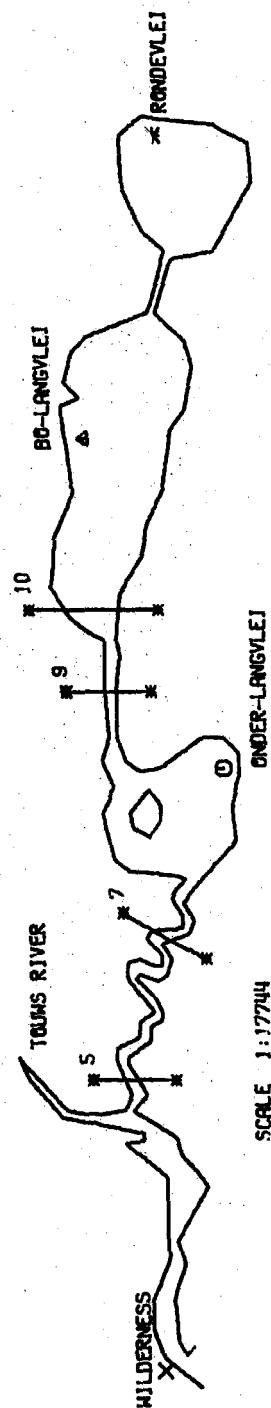
FIGURE
17.1d



ORIGINAL LAYOUT WITH SILL SCOURING TO 1.0 M.
 (HEIGHT=2M, WIDTH=40M, LENGTH=120M) INITIAL LEVEL: 1.8 M.
 FLOOD: 1 IN 100 YEAR. MAXIMUM DISCHARGE: 278.3 M³/S.



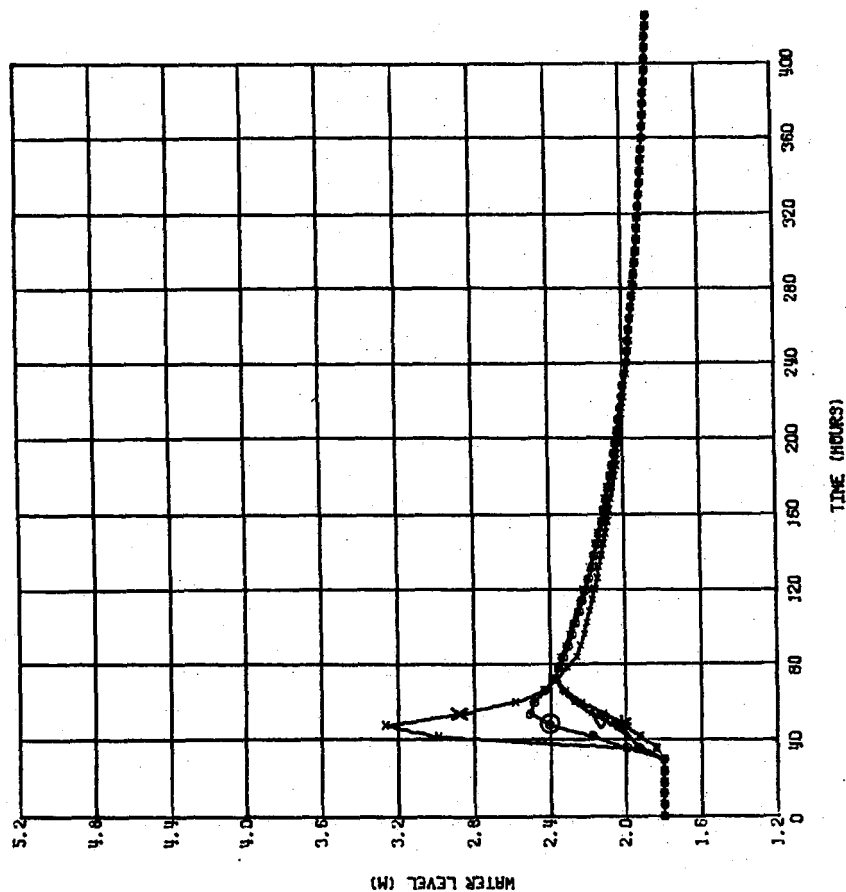
ORIGINAL LAYOUT. INITIAL LEVEL: 1.8 M. TO NSL.
 FLOOD: 1 IN 100 YEAR. MAXIMUM DISCHARGE: 278.3 M³/S.



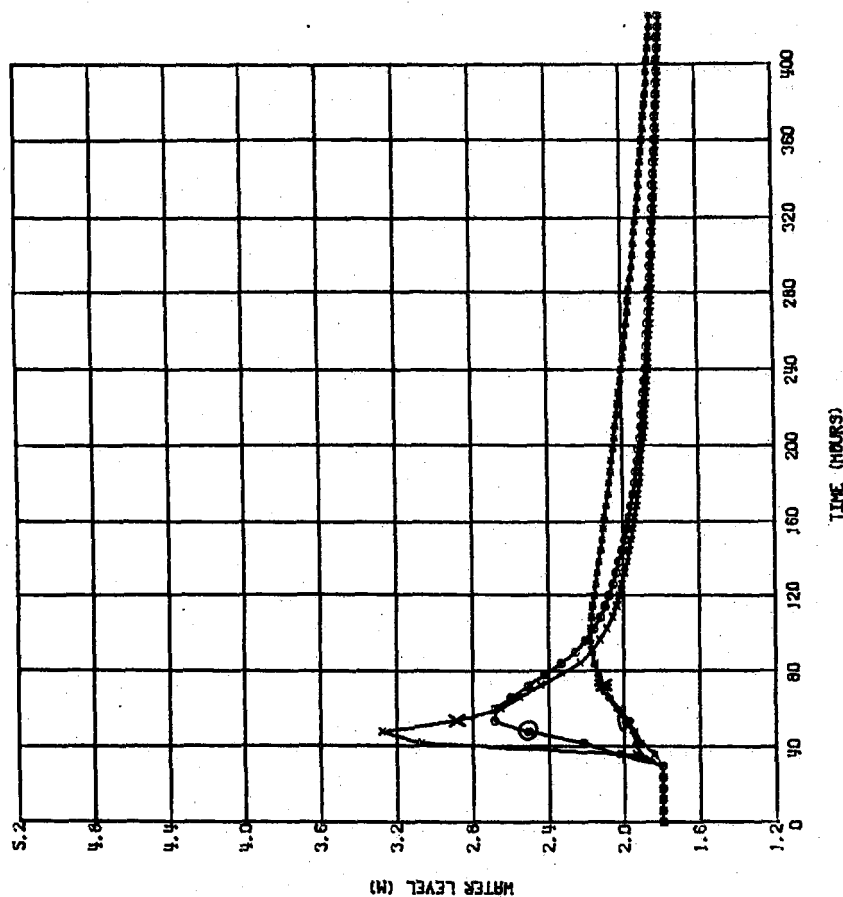
TRACED : COMLOT
 CHECKED :
 DATE : 1980-08-30
 REF. : C/SEA 8113

WILDERNESS NUMERICAL STUDY
 ORIGINAL LAYOUT WITH SCOURING SILL (H=2,
 B=40M, L=120M) FLOOD: 1 IN 100 YEAR.

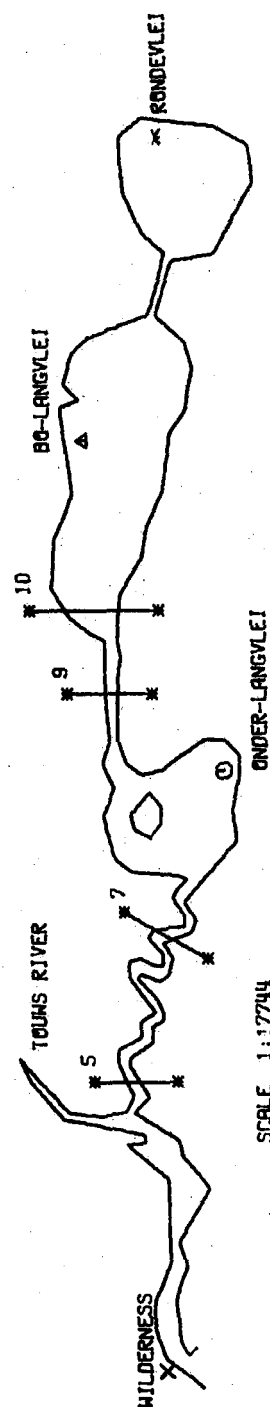
FIGURE
 17.1e



DREDGED LAYOUT WITH SILL SCOURING TO 1.0 M.
 (HEIGHT=2M, WIDTH=40M, LENGTH=120M) INITIAL LEVEL: 1.8 M.
 FLOOD: 1 IN 50 YEAR. MAXIMUM DISCHARGE: 183.1 M³/S.



ORIGINAL LAYOUT WITH SILL SCOURING TO 1.0 M.
 FLOOD: 1 IN 50 YEAR. MAXIMUM DISCHARGE: 183.1 M³/S.
 INITIAL LEVEL 1.8 M TO NSL.

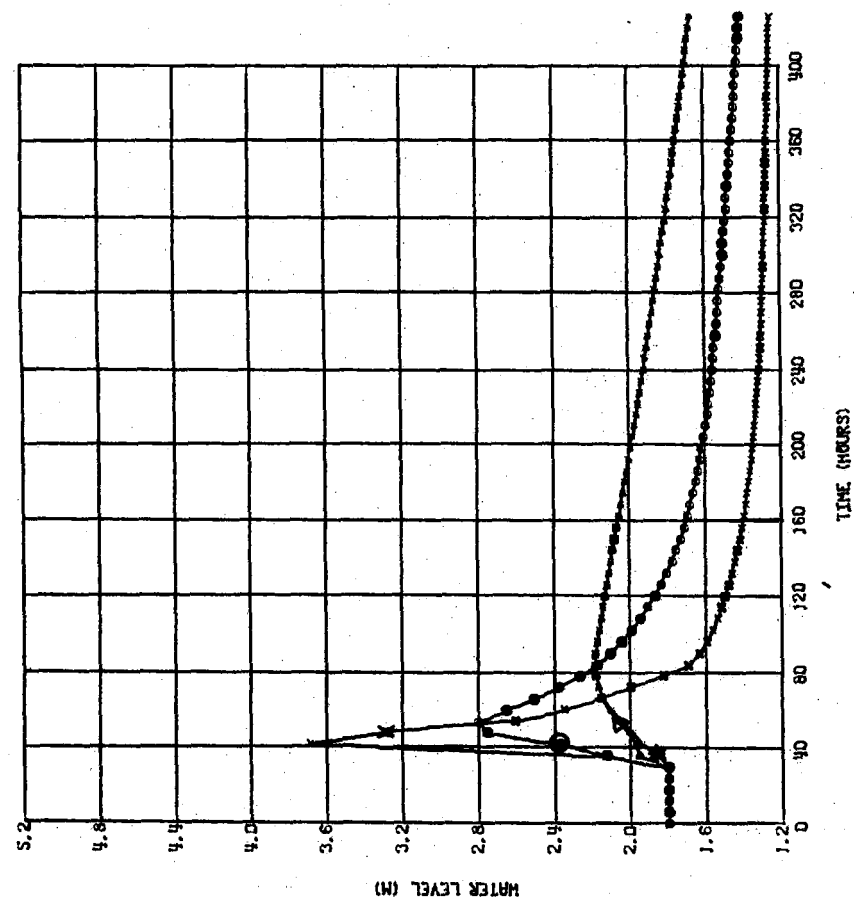


SCALE 1:17744

TRACED : COMPILOT
 CHECKED :
 DATE : 1980-08-30
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WILDERNESS NUMERICAL STUDY
 DREDGED LAYOUT WITH SCOURING SILL (H=2,
 B=40M, L=120M) FLOOD: 1 IN 50 YEAR.

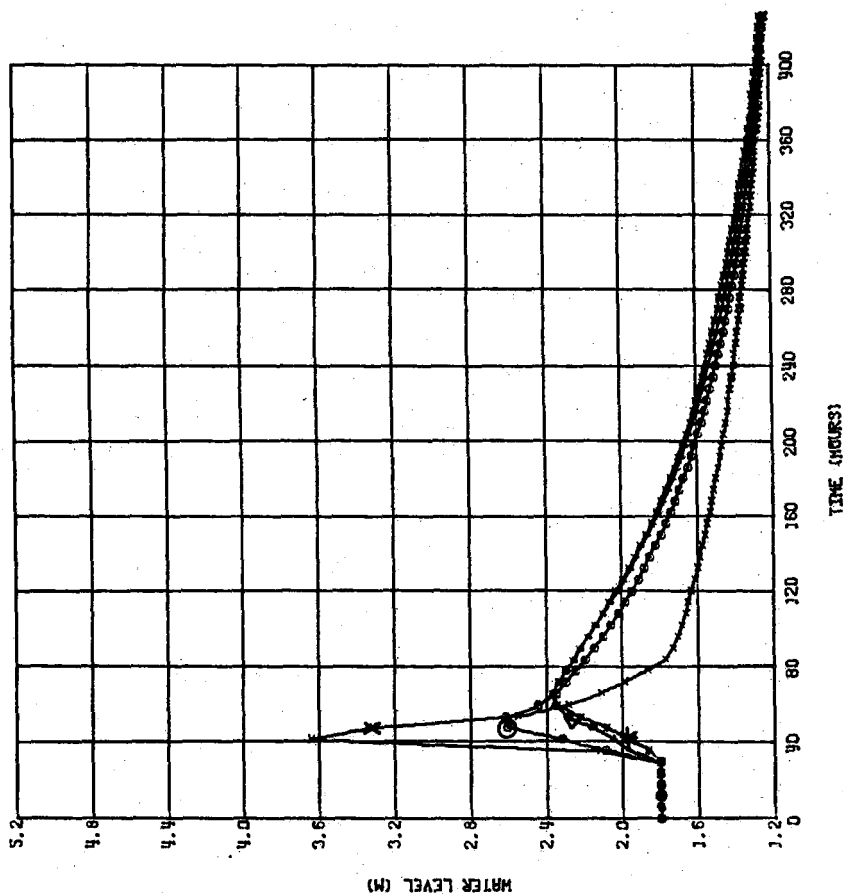
FIGURE
 17.2a



ORIGINAL LAYOUT WITH SILL SCOURING TO 1.0 M.

FLOOD: 1 IN 100 YEAR. MAXIMUM DISCHARGE: 278.3 M^3/S .

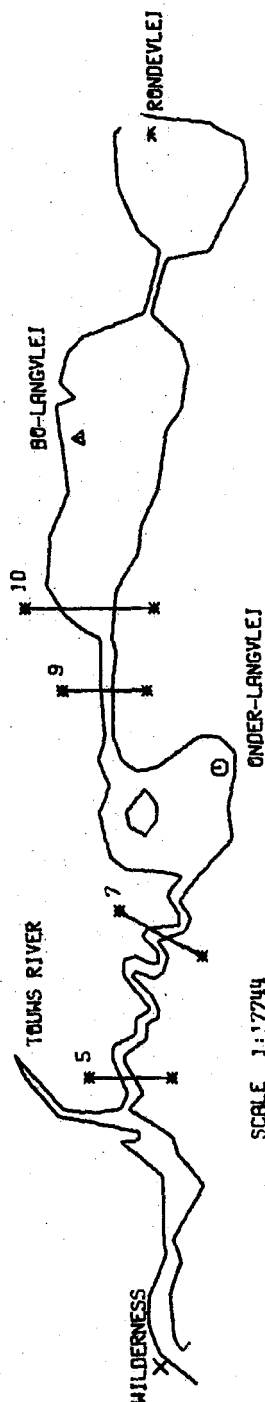
INITIAL LEVEL 1.8 M TO MSL.



DREDGED LAYOUT WITH SILL SCOURING TO 1.0 M.

HEIGHT=2M, WIDTH=40M, LENGTH=120M INITIAL LEVEL: 1.8 M.

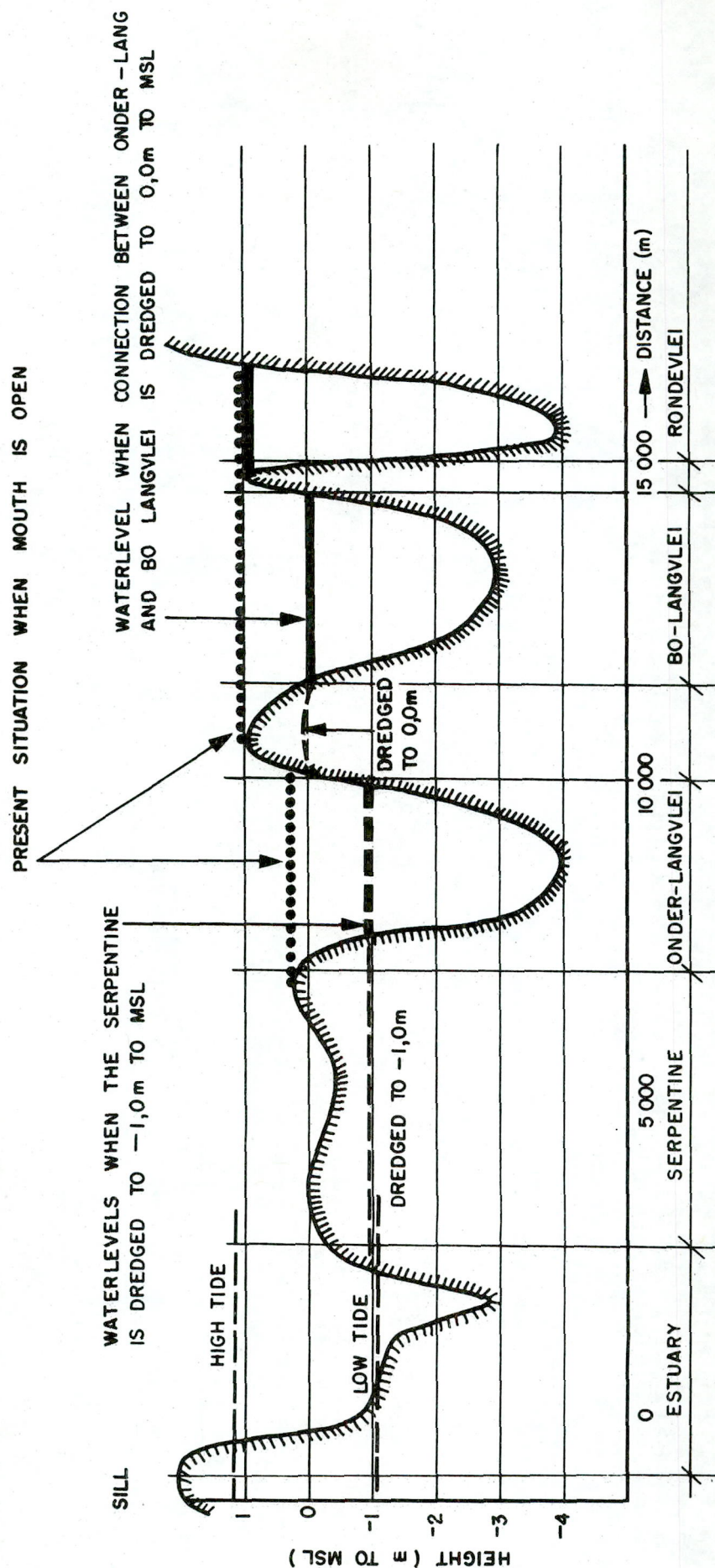
FLOOD: 1 IN 100 YEAR. MAXIMUM DISCHARGE: 278.3 M^3/S .



TRACED : COMPLIT
CHECKED :
DATE : 1980-08-30
REF. : C/SEA 8113

WILDERNESS NUMERICAL STUDY
DREDGED LAYOUT WITH SCOURING SILL (H=2,
B=40M, L=120M) FLOOD: 1 IN 100 YEAR.

FIGURE
17.2b



TRACED : P.A.N.
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 DATE : July 1981
 REF : C/SEA 8113

WILDERNESS NUMERICAL STUDY
 LONGITUDINAL SECTION OF THE LAKES TO
 ILLUSTRATE MINIMUM WATERLEVELS FOR
 DIFFERENT DREDGED SCHEMES

FIGURE
 18

APPENDIX A.1

HYDROLOGICAL RESEARCH UNIT

SPECIAL REPORT 1/79

ESTIMATED FLOOD HYDROGRAPHS FOR CERTAIN WILDERNESS STREAMS

by

A.H.M. GÖRGENS

SENIOR RESEARCH FELLOW

September 1979

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LIST OF FIGURES

A1a-c	Flood hydrographs for the rivers at Wilderness lakes
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1. BACKGROUND

At a meeting of the Coastal Lakes Working Group at Wilderness on 14 September 1979 the Hydrological Research Unit of Rhodes University was requested to develop 'first estimate' flood hydrographs of certain Wilderness streams required as input during a first tentative operation of an estuary/lake model of the Wilderness Lugune/Eilandvlei/Langvlei/Rondevlei system, developed by the National Research Institute for Oceanology at Stellenbosch. In this report flood hydrographs covering a range of return periods pertaining to the Touw and Duiwe Rivers and the Langvlei Spruit are presented, along with some basic catchment information.

2. ESTIMATION TECHNIQUES

The aforementioned flood hydrographs were calculated on the basis of the well-known 'unitgraph' theory, while storm data and design criteria relevant to the Wilderness region were extracted from Reports 2/78 and 1/72 of the Hydrological Research Unit of the University of the Witwatersrand.

It should be noted that these 'first estimates' can be improved upon by the use of more advanced areal storm synthesis and hydrograph separation techniques, as well as the recently innovated 'runhydrograph' techniques. The limited immediate objectives of the estuary/lake model users, however, did not warrant the additional time and effort required by the more advanced techniques.

The best answer to the need for accurate and representative flood hydrographs lies in the long run in simulation models of the rainfall-runoff processes in river catchments. Unfortunately, calibration and verification of such models are time-consuming tasks and first results of the approach to the Wilderness catchments will only be forthcoming in 1980.

3. CATCHMENT INFORMATION

Only rivers and streams affecting water levels in the Lakes system comprising the Rondevlei, Langvlei, Eilandvlei, Serpentine, Wilderness Lagune and their interconnecting channels, are considered in this Report. Of these, only three

streams, the Touw River, the Duiwe/Klein-Keurbooms River and an unnamed stream flowing into the upper Langvlei (which is called the Langvlei Spruit for convenience), can be regarded as major flood producing streams. The microcatchments of the lakes themselves are ignored.

4. FLOOD HYDROGRAPHS

Characteristics of the catchments of the main contributors to the lakes are given in Table A1/I. Flood hydrographs (1 in 5, 10, 20, 50 and 100 year) for the Touw River, Duiwe/Klein-Keurbooms River and Langvlei Spruit, determined by the Hydrological Research Unit of Rhodes University, based on the unit hydrograph theory are given in Tables A1/II-IV and have been plotted in Figures Ala-c.

TABLE A1/I: CATCHMENT CHARACTERISTICS

Catchment	Touw River	Duiwe River	Langvlei Spruit
Area (km ²)	103	34	9
Mean annual precipitation (mm)	915	910	900
Mean annual runoff (m ³)	22,6 x 10 ⁶	6,0 x 10 ⁶	1,5 x 10 ⁶
Longest water course (km)	33	17	9
Average slope (%)	2,9	4,2	3,9
Basin lag time (hrs)	12	6	4
Critical storm duration (hrs)	4	2	1,25

TABLE A1/II: FLOOD HYDROGRAPHS: TOUW RIVER

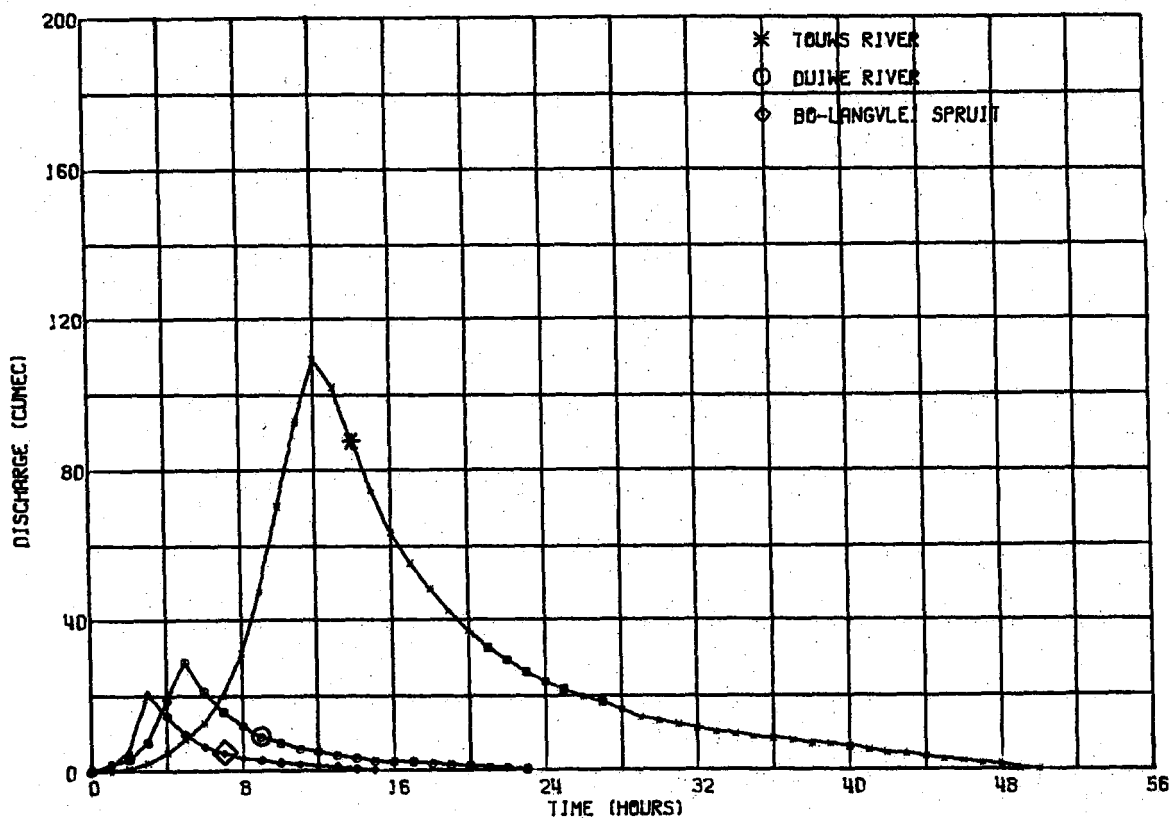
Time (hours)	Flow rates in m ³ /s for return periods:			
	5 year	10 year	20 year	50 year
1	0,2	0,2	0,3	0,3
2	0,8	0,9	1,2	1,3
3	2,1	2,7	3,3	3,6
4	4,9	6,5	7,8	8,3
5	8,5	11,5	13,6	14,6
6	12,8	17,3	20,5	22,0
7	19,7	26,6	31,6	33,9
8	30,9	41,4	29,1	53,0
9	47,5	63,8	75,9	81,4
10	70,3	94,9	112,1	120,4
11	92,7	125,3	145,8	158,1
12	109,1	145,7	170,4	183,1
13	101,7	136,9	160,3	172,2
14	87,6	117,9	138,0	148,2
15	74,5	100,3	117,4	125,9
16	63,3	85,5	100,0	107,3
17	55,2	74,5	87,3	93,6
18	48,3	65,0	76,1	81,8
19	42,3	56,9	66,5	71,5
20	37,1	50,0	58,5	62,7
21	32,5	43,8	51,4	55,1
22	29,1	39,3	46,1	49,6
23	26,0	35,0	41,1	44,1
24	23,3	31,3	36,7	39,4
25	21,2	28,5	33,4	36,0
26	19,3	25,9	30,3	32,7
27	17,9	23,9	28,2	30,1
28	16,0	21,5	25,2	27,1
29	13,9	19,5	22,9	24,5
30	13,3	17,8	21,0	22,6
31	12,2	16,4	19,2	20,7
32	11,2	15,2	17,7	19,1
33	10,2	13,9	16,4	17,5
34	9,6	13,1	15,4	16,5
35	8,8	12,3	14,4	15,4
36	8,5	11,6	13,6	14,7
37	7,9	10,8	12,7	13,7
38	7,2	9,9	11,6	12,6
39	6,8	9,4	10,8	11,5
40	6,1	8,4	9,9	10,5
41	5,3	7,3	8,6	9,2
42	4,5	6,5	7,6	8,1
43	4,2	5,8	6,8	7,4
44	3,6	5,0	5,9	6,4
45	2,9	4,1	4,7	5,2
46	2,5	3,4	3,8	4,2
47	1,9	2,4	2,8	2,9
48	1,4	1,7	1,8	1,9
49	0,5	0,8	0,9	0,9
50	0,2	0,3	0,3	0,4
51	0,0	0,0	0,0	0,0

TABLE A1/III: FLOOD HYDROGRAPHS: DUIWE/KLEIN-KEURBOOMS RIVER

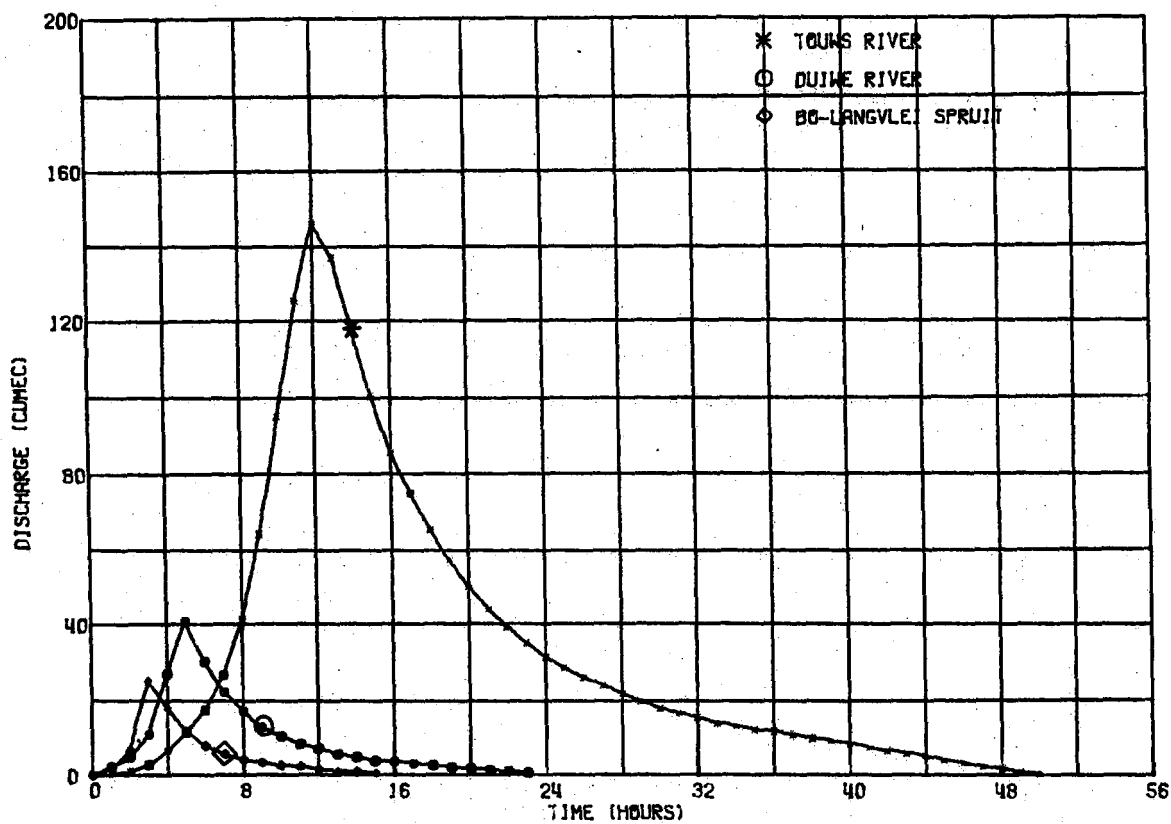
Time (hours)	Flow rate in m ³ /s for return periods:			
	5 year	10 year	20 year	50 year
1	1,7	2,4	2,8	3,7
2	3,3	4,7	5,5	7,4
3	7,6	10,8	12,7	17,0
4	18,8	26,8	31,4	42,2
5	28,7	40,9	47,9	64,4
6	21,1	30,1	35,2	47,4
7	15,5	22,1	25,9	34,8
8	11,9	16,9	19,8	26,6
9	8,9	12,7	14,9	20,0
10	7,3	10,3	12,1	16,3
11	5,9	8,5	9,9	13,3
12	5,0	7,1	8,3	11,1
13	4,0	5,6	6,6	8,9
14	3,3	4,7	5,5	7,4
15	2,6	3,8	4,4	5,9
16	2,4	3,5	4,0	5,4
17	2,2	3,1	3,6	4,8
18	1,8	2,6	3,0	4,1
19	1,5	2,1	2,5	3,3
20	1,2	1,7	1,9	2,6
21	0,8	1,2	1,4	1,9
22	0,7	0,9	1,1	1,5
23	0,3	0,5	0,6	0,7
24	0,0	0,0	0,0	0,0

TABLE A1/IV: FLOOD HYDROGRAPHS: LANGVLEI SPRUIT

Time (hours)	Flow rate in m ³ /s for return periods:			
	5 year	10 year	20 year	50 year
1	1,5	1,9	2,4	3,2
2	5,4	6,7	8,5	11,3
3	20,4	25,2	32,0	42,8
4	14,4	17,8	22,6	30,2
5	9,6	11,8	15,0	20,2
6	6,3	7,8	9,9	13,2
7	4,5	5,6	7,1	9,5
8	3,3	4,1	5,2	6,9
9	2,7	3,3	4,2	5,7
10	2,1	2,6	3,3	4,4
11	1,8	2,2	2,8	3,8
12	1,2	1,5	1,9	2,5
13	0,9	1,1	1,4	1,9
14	0,6	0,7	0,9	1,3
15	0,3	0,4	0,5	0,6
16	0,0	0,0	0,0	0,0



1 IN 5 YEAR FLOOD HYDROGRAPH



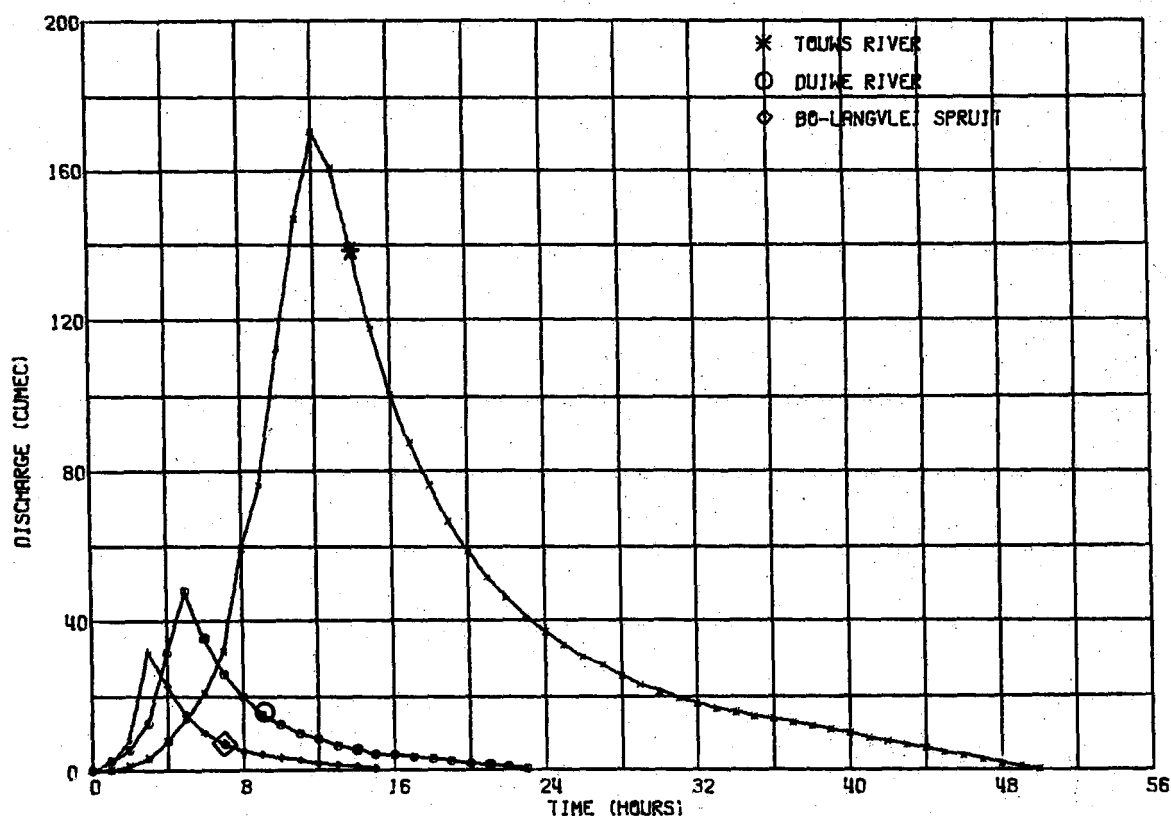
1 IN 10 YEAR FLOOD HYDROGRAPH

CALCULATED BY THE HYDROLOGICAL RESEARCH UNIT
OF RHODES UNIVERSITY. (SPECIAL REPORT 1/79)

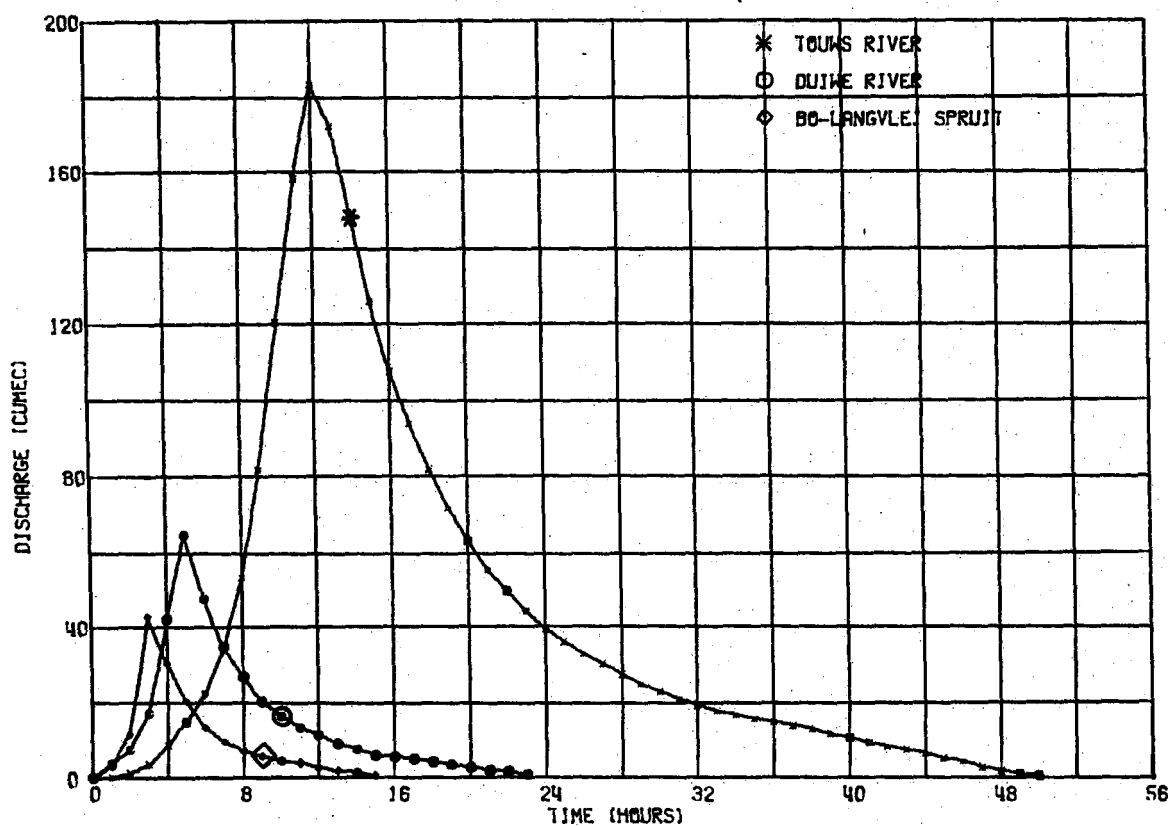
TRACED : COMPLIT
CHECKED :
DATE : 1980-08-30
REF. : C/SEA 8/13

WILDERNESS NUMERICAL STUDY
FLOOD HYDROGRAPHS FOR THE
RIVERS AT WILDERNESS LAKES.

FIGURE
A.1a



1 IN 20 YEAR FLOOD HYDROGRAPH



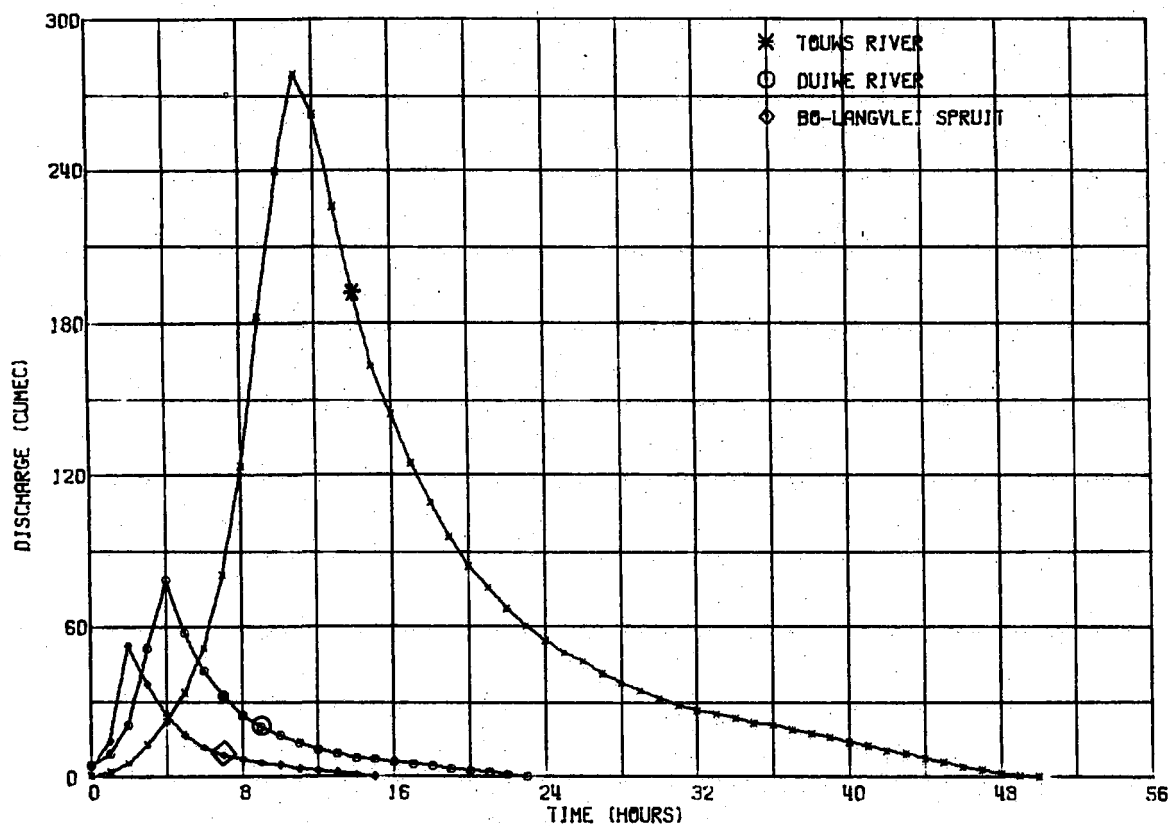
1 IN 50 YEAR FLOOD HYDROGRAPH

CALCULATED BY THE HYDROLOGICAL RESEARCH UNIT
OF RHODES UNIVERSITY. (SPECIAL REPORT 1/79)

TRACED : COMLOT
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DATE : 1980-08-30
REF. : C/SEA 8/13

WILDERNESS NUMERICAL STUDY
FLOOD HYDROGRAPHS FOR THE
RIVERS AT WILDERNESS LAKES.

FIGURE
A.1b



1 IN 100 YEAR FLOOD HYDROGRAPH:

CALCULATED BY THE HYDROLOGICAL RESEARCH UNIT
OF RHODES UNIVERSITY. (SPECIAL REPORT 1/79)

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DATE : 1980-08-30
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WILDERNESS NUMERICAL STUDY
FLOOD HYDROGRAPHS FOR THE
RIVERS AT WILDERNESS LAKES.

FIGURE
A.1c

APPENDIX A.2

HYDROLOGICAL RESEARCH UNIT

SPECIAL REPORT 1/80

RUNHYDROGRAPHS FOR THREE WILDERNESS STREAMS

by

A.H.M. GÖRGENS

SENIOR RESEARCH FELLOW

September 1980

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Table A2/II	Duiwe/Klein-Keurbooms River: Flood hydrograph for the 100 year return period flood	A14
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LIST OF FIGURES

Figure A.2a-e Run hydrographs (No. 1-5) for the rivers
at Wilderness lakes

1. BACKGROUND

This document reports on the continuation of work described in the Hydrological Research Unit's Special Report 1/79, 'Estimated flood hydrographs for certain Wilderness streams', dated September 1979. Preliminary operations of the estuary/lake model of the Wilderness Lakes system by the National Research Institute for Oceanology (Stellenbosch) using as input data the 1:5 to 1:50 year flood hydrographs supplied in the above report, showed that the range of floods investigated should be extended to include the 1:100 year events. The effects of the 1:50 and 1:100 year floods, respectively, on lake water levels are furthermore regarded by the Lakes Areas Development Board (George) as focal points of the Board's interest in the present modelling studies of the lakes system.

To meet these needs, two suites or 'families' of 1:50 and 1:100 year flood hydrographs, based on the theory of runhydrographs, were calculated (for each of the three streams providing most of the lake inflows) and are presented in this report for wider use. Included for comparative purposes is also a 1:100 year flood hydrograph for each storm, based on traditional unitgraph theory.

2. ESTIMATION TECHNIQUES

Since completion of Special Report 1/79, a powerful new technique for design flood hydrograph generation has become available through the publication of the Water Research Commission Report, 'The runhydrograph - theory and application for flood predictions', (May 1979), by L.A.V. Hiemstra and D.M. Francis. This technique, which is based on the statistical theory of runs, makes it possible to define a flood in terms of two variables, that is, the instantaneous peak rate of flow, as well as the associated flood volume.

By satisfactorily fitting flood peaks vs. volumes from all suitable South African streamflow records to the bivariate lognormal distribution function, the above authors have made possible the calculation of the probability of exceedance, in other words, the return period, of any combination of flood

peak and associated volume for any catchment in South Africa. This fact obviously also means that for each return period an almost infinite 'family' of flood hydrographs exists - in contrast to the unitgraph approach which allows only a single, unique flood hydrograph for each return period. Also in terms of the definition of return period, the runhydrograph is more precise than the unitgraph product. The latter derives its return period from its causative design storm, which is a dubious assumption, whereas the return period of the former is based on probability analysis of actual streamflows. Clearly, the runhydrograph approach is more realistic, and in an investigation where flood volume is as important as flood peak, such as the Wilderness Lakes study, the significance of the results is greatly enhanced by using a range of input flood hydrographs representing different combinations of peaks and volumes, but all having the same return period.

Using the above report, two families of five representative runhydrographs each of return periods 1:50 and 1:100 years, respectively, were generated for the Touw River, the Duiwe/Klein-Keurbooms River and the Langvlei Spruit, respectively - these three rivers being the major sources of inflow into the Lakes. Listing of the runhydrographs were provided to NRIO and have been plotted as Figures A2a-e.

For comparative purposes, 1:100 year flood hydrographs based on unitgraph theory and using storm data and design criteria for the Wilderness region supplied in Reports 1/72 and 2/78 of the Hydrological Research Unit of the University of the Witwatersrand, were calculated and are given in Tables A2/I-III.

3. INTERPRETATION OF THE RUNHYDROGRAPHS

Comparison of the unitgraph 1:50 and 1:100 year hydrographs with the equivalent runhydrographs reveals that the unitgraph technique usually leads to a higher peak than the runhydrograph with the equivalent volume, and in each of the six families shown, the unitgraph produce seems to slot somewhere between runhydrographs No. 3 and No. 4, in terms of volume, but near or beyond runhydrograph No. 1 in terms of peak flow rate.

Considering that a very 'conservative' approach was followed in the run-hydrograph calculation procedure, it would seem that the unitgraph method over-estimates severely (a fact confirmed by Prof. Hiemstra in recent personal communication on this matter).

As a further point of interest it can be noted that runhydrograph No. 3 was in each case selected to represent the central member of each infinite family of hydrographs and that peak/volume combinations in between or beyond the members of the families shown, can easily be generated and supplied on request.

4. FURTHER HYDROLOGICAL RESEARCH

The Rhodes Hydrological Research Unit is at present reconstructing the historical flow records of all important rivers and streams in the George-Knysna region using conceptual rainfall-runoff models. This work, as well as other relevant climatological and physiographic information, will be presented in a report early in 1981, entitled 'Hydrological investigations in the southeastern coastal lakes area'.

TABLE A2/I: TOUW RIVER: FLOOD HYDROGRAPH FOR 100 YEAR RETURN PERIOD FLOOD
(Unitgraph method)

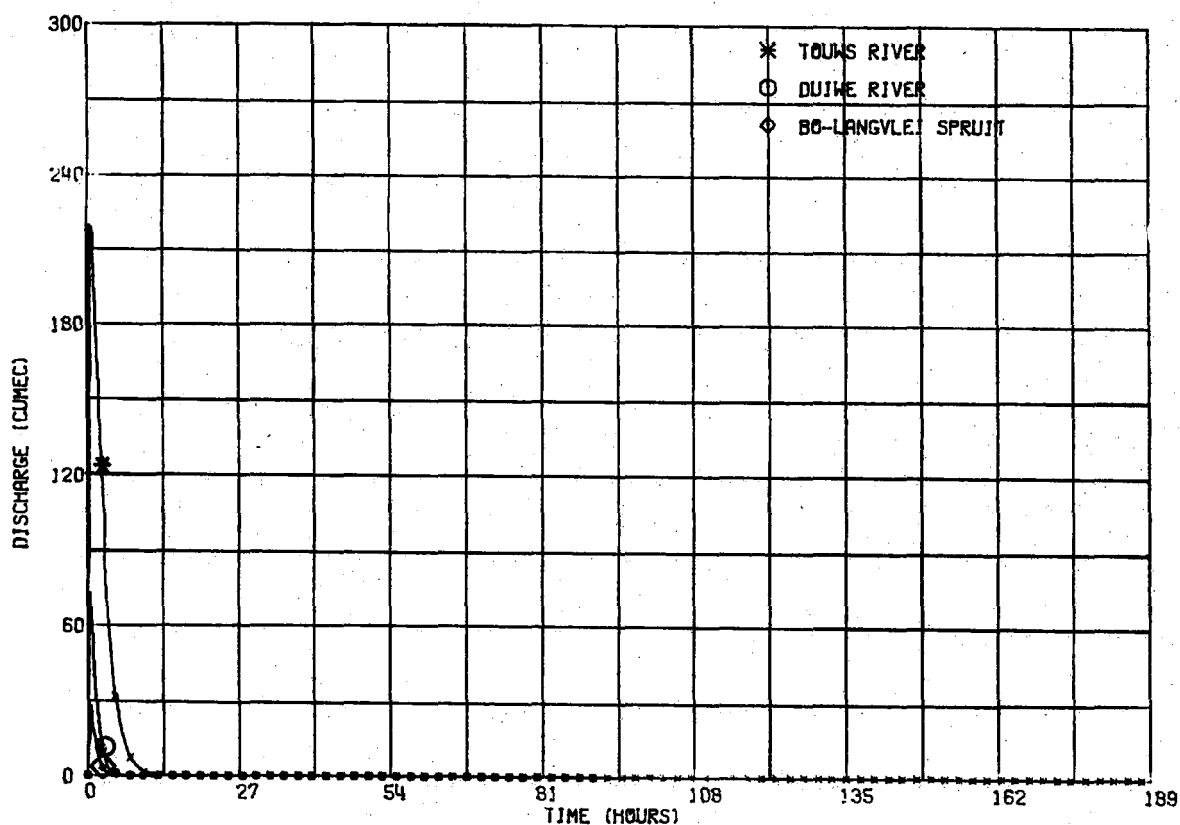
<u>Time</u> <u>(hours)</u>	<u>Flow rate</u> <u>(m³/s)</u>
1	0,4
2	1,8
3	5,3
4	12,5
5	22,0
6	33,4
7	51,3
8	80,3
9	123,4
10	182,2
11	239,4
12	278,3
13	261,8
14	225,5
15	191,8
16	163,3
17	144,4
18	124,4
19	108,8
20	95,5
21	83,9
22	75,2
23	66,9
24	60,0
25	54,5
26	49,6
27	45,9
28	41,1
29	37,3
30	34,1
31	31,3
32	28,6
33	26,1
34	24,9
35	23,1
36	21,4
37	20,5
38	18,7
39	17,0
40	15,5
41	13,8
42	12,0
43	10,3
44	9,3
45	7,1
46	5,9
47	3,9
48	2,7
49	1,3
50	0,5
51	0,0

TABLE A2/II: DUIWE/KLEIN-KEURBOOMS RIVER: FLOOD HYDROGRAPH FOR 100 YEAR
RETURN PERIOD FLOOD (Unitgraph method)

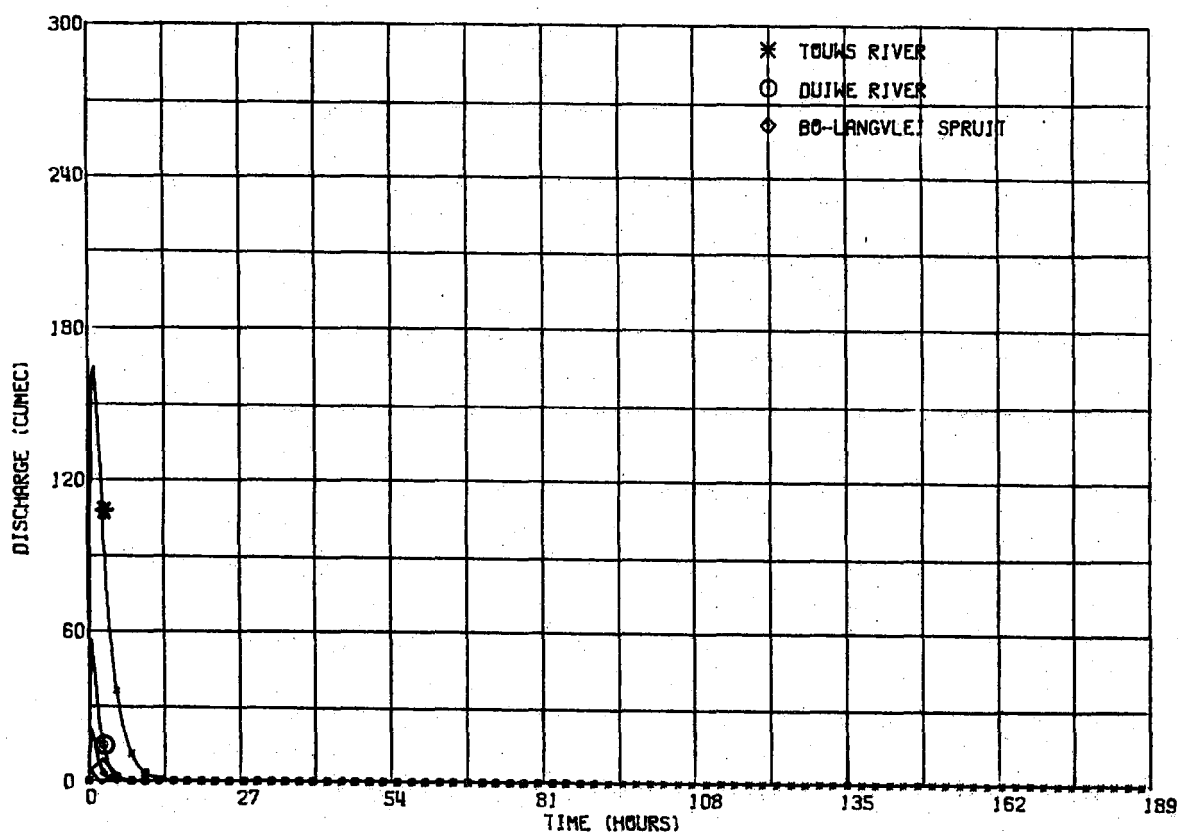
<u>Time</u> <u>(hours)</u>	<u>Flow rate</u> <u>(m³/s)</u>
1	4,5
2	9,0
3	20,7
4	51,3
5	78,3
6	57,6
7	42,3
8	32,4
9	24,3
10	19,8
11	16,2
12	13,5
13	10,8
14	9,0
15	7,2
16	6,8
17	5,9
18	5,0
19	4,1
20	3,2
21	2,3
22	1,8
23	0,9
24	0,0

TABLE A2/III: LANGVLEI SPRUIT: FLOOD HYDROGRAPH FOR 100 YEAR RETURN PERIOD FLOOD
(Unitgraph method)

<u>Time</u> <u>(hours)</u>	<u>Flow rate</u> <u>(m³/s)</u>
1	3,9
2	13,9
3	52,4
4	37,0
5	24,6
6	16,2
7	11,6
8	8,5
9	6,9
10	5,4
11	4,6
12	3,1
13	2,3
14	1,5
15	0,8
16	0,0



1 IN 100 YEAR RUNHYDROGRAPH



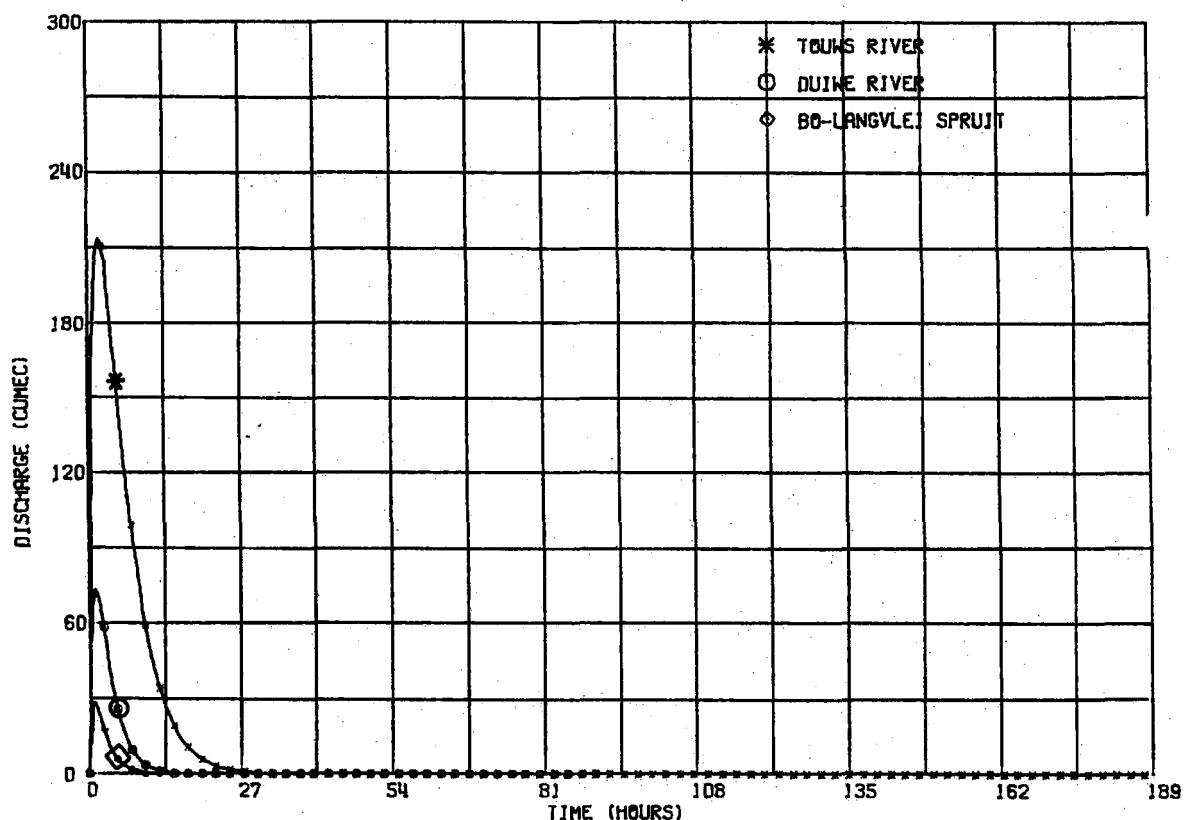
1 IN 50 YEAR RUNHYDROGRAPH

CALCULATED BY THE HYDROLOGICAL RESEARCH UNIT
OF RHODES UNIVERSITY. (SPECIAL REPORT 1/80)

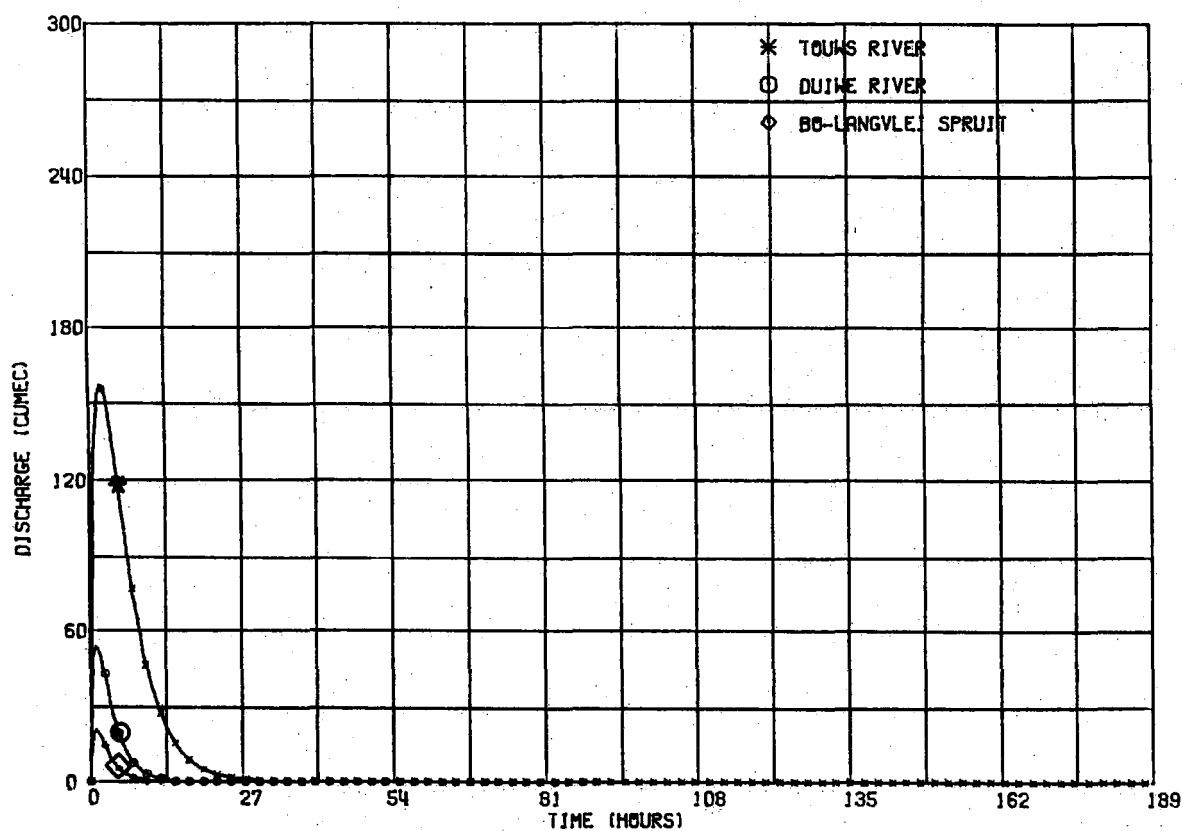
TRACED : COMPLIT
CHECKED :
DATE : 1980-08-30
REF. : C/SEA 8113

WILDERNESS NUMERICAL STUDY
RUNHYDROGRAPHS (NO.1) FOR THE
RIVERS AT WILDERNESS LAKES.

FIGURE
A.2a



1 IN 100 YEAR RUNHYDROGRAPH



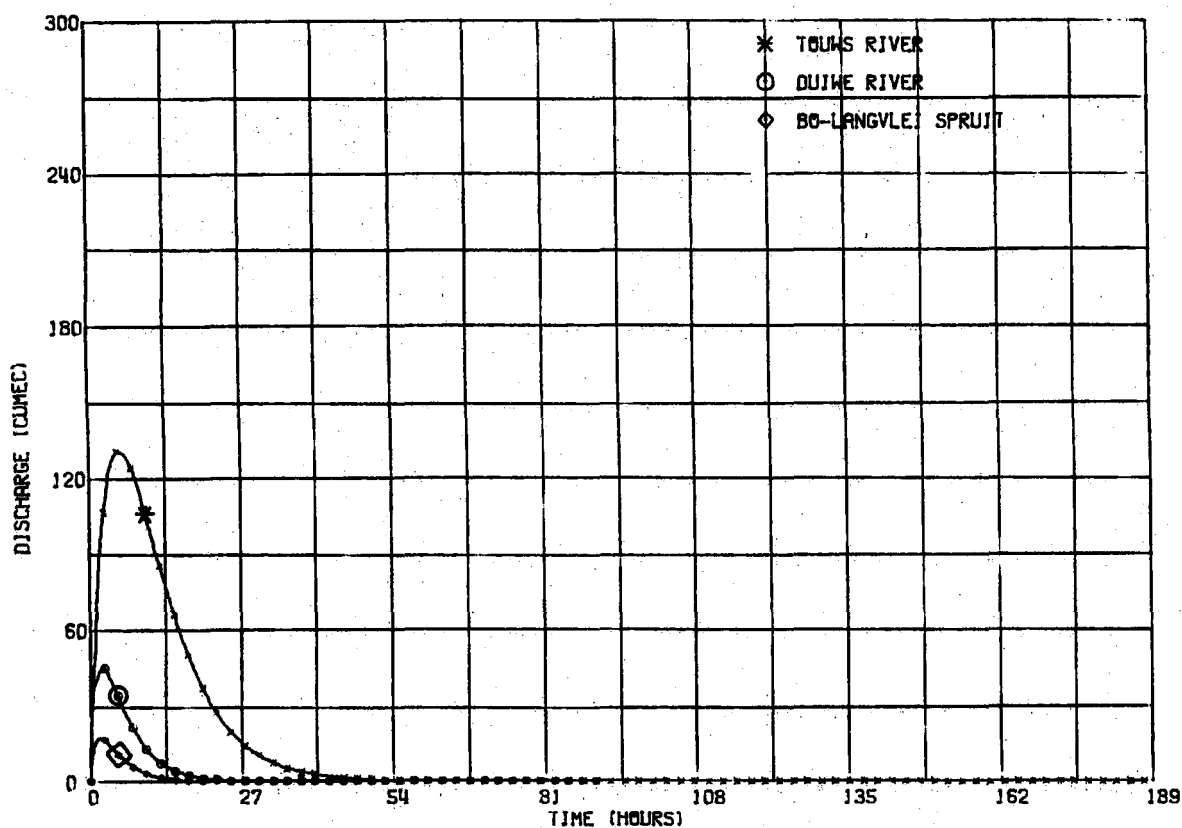
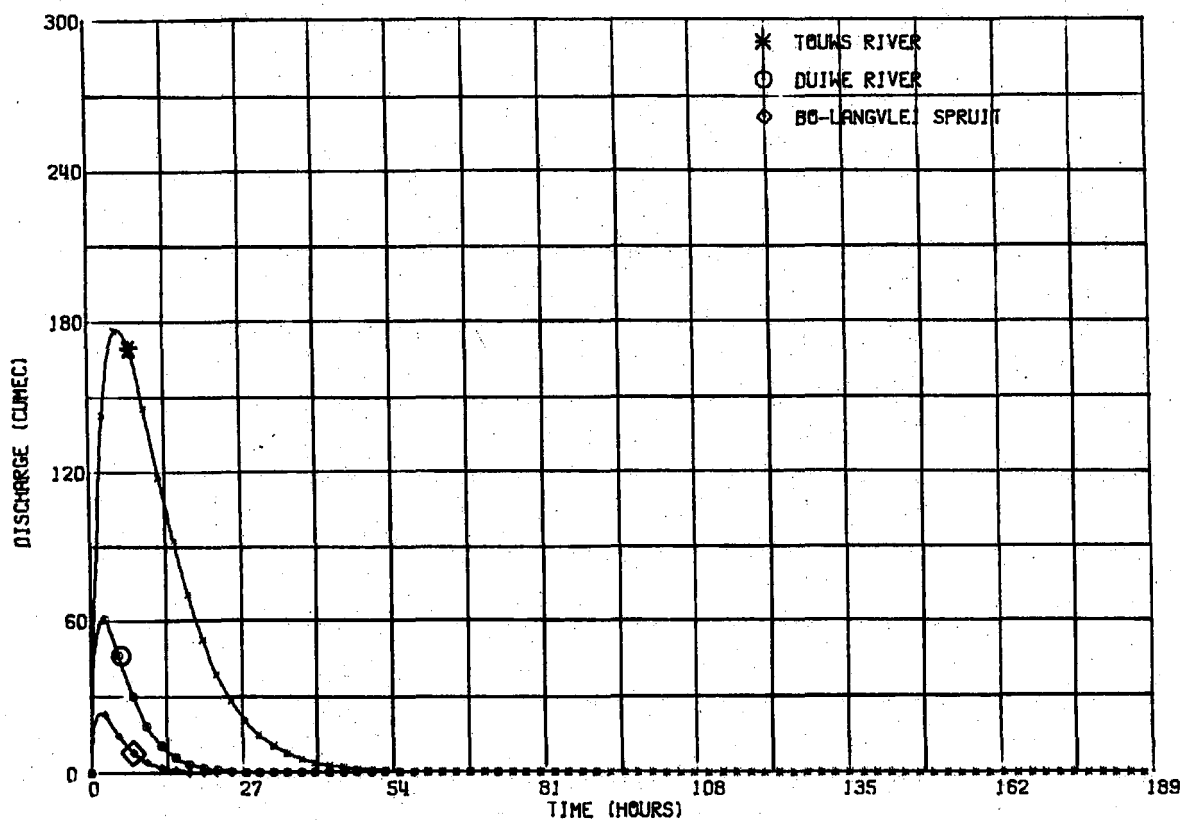
1 IN 50 YEAR RUNHYDROGRAPH

CALCULATED BY THE HYDROLOGICAL RESEARCH UNIT
OF RHODES UNIVERSITY. (SPECIAL REPORT 1/80)

TRACED : COMPLIT
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DATE : 1980-08-30
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WILDERNESS NUMERICAL STUDY
RUNHYDROGRAPHS (NO.2) FOR THE
RIVERS AT WILDERNESS LAKES.

FIGURE
A.2b

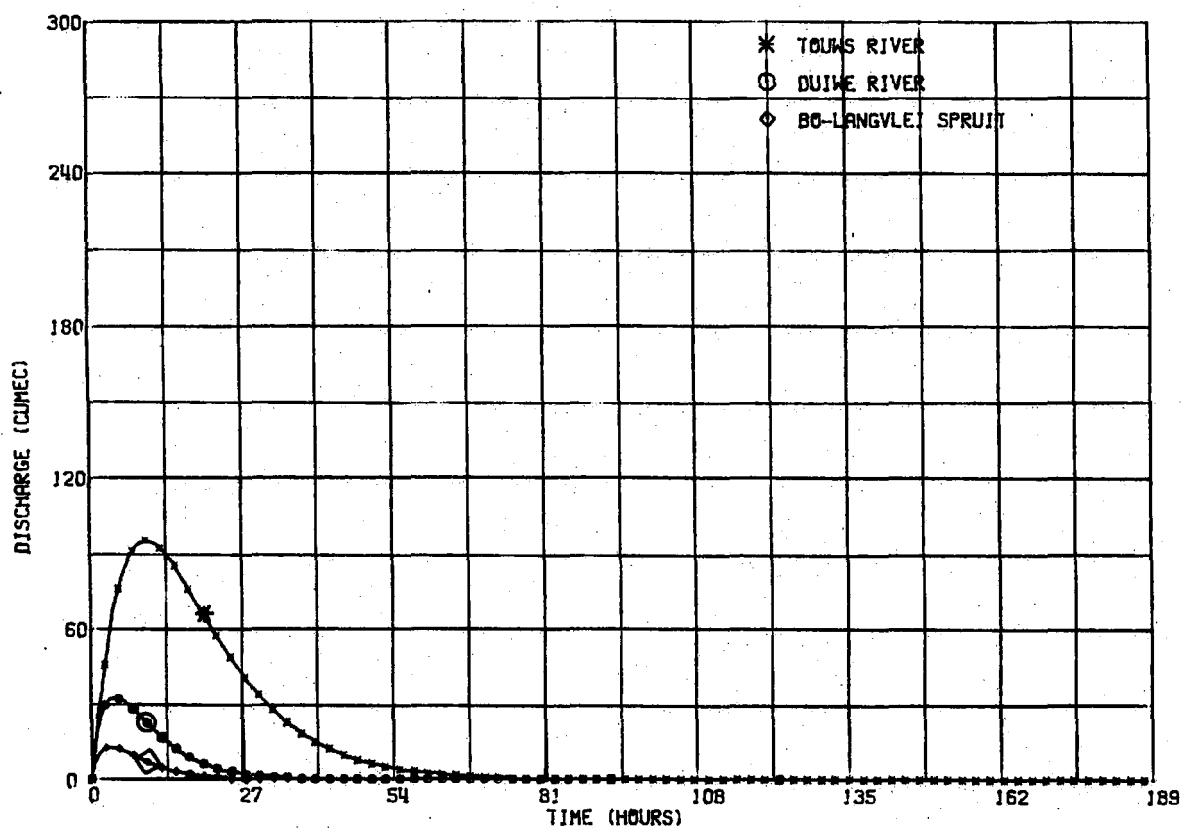
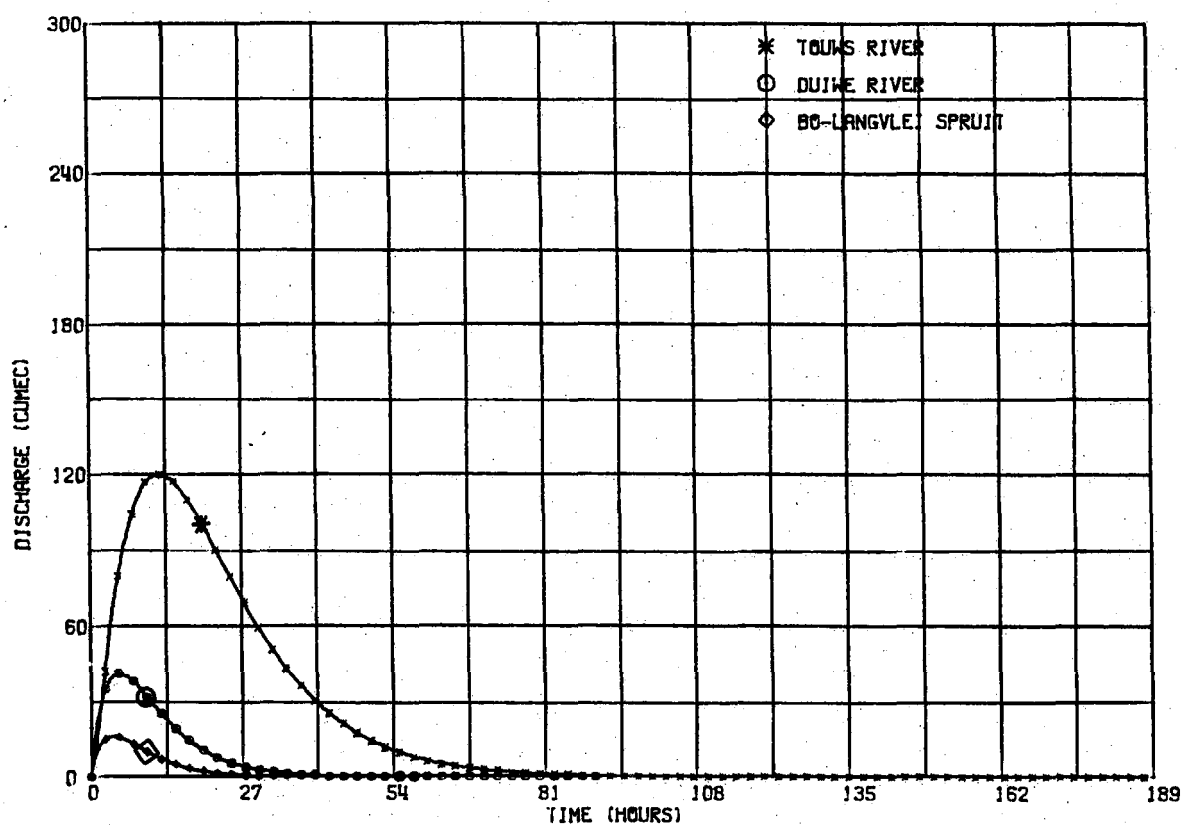


CALCULATED BY THE HYDROLOGICAL RESEARCH UNIT
OF RHODES UNIVERSITY. (SPECIAL REPORT 1/80)

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DATE : 1980-08-30
REF. : C/SEA 8113

WILDERNESS NUMERICAL STUDY
RUNHYDROGRAPHS (NO.3) FOR THE
RIVERS AT WILDERNESS LAKES.

FIGURE
A.2c

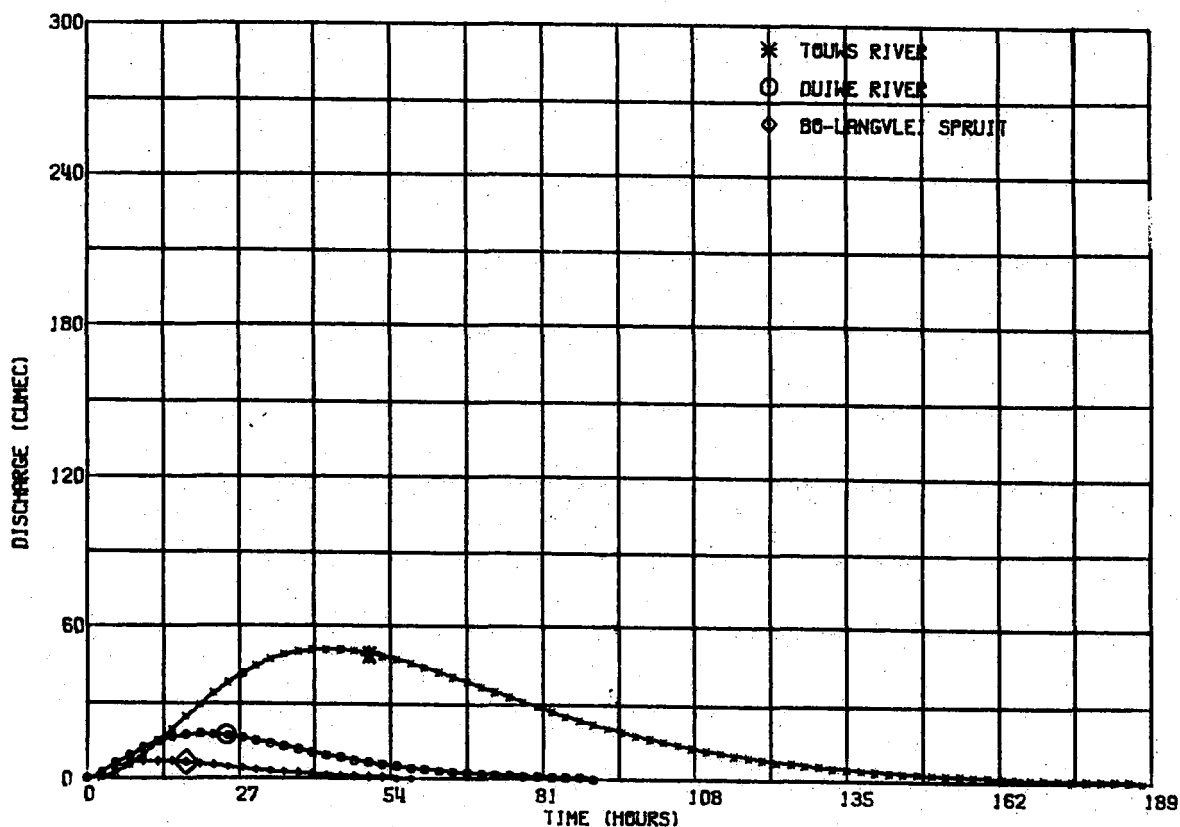


CALCULATED BY THE HYDROLOGICAL RESEARCH UNIT
OF RHODES UNIVERSITY. (SPECIAL REPORT 1/80)

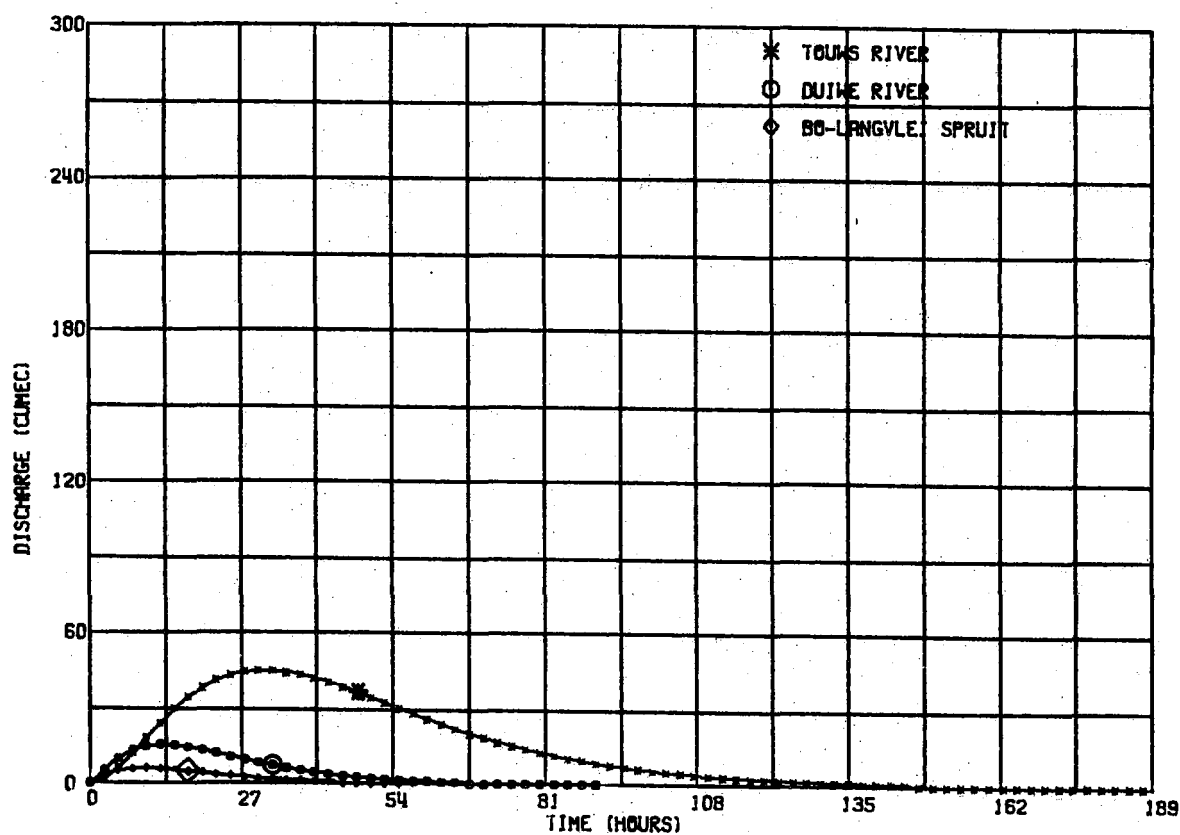
TRACED : COMLOT
CHECKED :
DATE : 1980-08-30
REF. : C/SEA 8113

WILDERNESS NUMERICAL STUDY
RUNHYDROGRAPHS (NO.4) FOR THE
RIVERS AT WILDERNESS LAKES.

FIGURE
A.2d



1 IN 100 YEAR RUNHYDROGRAPH



1 IN 50 YEAR RUNHYDROGRAPH

CALCULATED BY THE HYDROLOGICAL RESEARCH UNIT
OF RHODES UNIVERSITY. (SPECIAL REPORT 1/80)

TRACED : COMPLIT
CHECKED :
DATE : 1980-08-30
REF. : C/SEA 8/13

WILDERNESS NUMERICAL STUDY
RUNHYDROGRAPHS (NO.5) FOR THE
RIVERS AT WILDERNESS LAKES.

FIGURE
A.2 e

APPENDIX B.1

COMPUTER PROGRAMS FOR THE WILDERNESS STUDY

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WILDERNESS ONE-DIMENSIONAL EXPLICIT MODEL

GENERAL

IN A RIVER THE MOTION OF THE TIDAL OR LONG WAVE IS CONSIDERED ONE-DIMENSIONAL. COMPONENTS OF ACCELERATION AND VELOCITY ARE SO SMALL COMPARED TO THE WAVE PROPAGATION IN TRANSVERSE AND VERTICAL DIRECTIONS THAT THEY MAY BE NEGLECTED.

ALONG A RIVER, CHOOSING THE X-AXIS IN UPSTREAM DIRECTION, THE EQUATION OF MOTION AT TIME T IS:

$$DH/DX = 1/GA(DQ/DT) - QQ/CCAAR + 2BQ/GAA(DH/DT) + W/3GR$$

WHERE: H = WATER LEVEL, X = DISTANCE UPSTREAM, Q = DISCHARGE, G = 9.81, A = CROSS-SECTIONAL AREA, B = STREAM WIDTH, T = TIME, C = CHEZY, R = HYD. RADIUS(A/B), W = WIND FACTOR

THE EQUATION FOR CONTINUITY OF FLOW:

$$DQ/DX = -BDH/DT$$

ALL DIFFERENTIAL QUOTIENTS IN ABOVE EQUATIONS CAN BE REFORMED TO DIFFERENCE QUOTIENTS AND BE SUBSTITUTED IN THE EQUATIONS. E.G.

$$DH/DX = (H(X+DX,T) - H(X-DX,T))/2DX \quad \text{AND}$$

$$DH/DT = (H(X,T+DT) - H(X,T-DT))/2DT$$

IN AN EXPLICIT SCHEME THE UNKNOWN VALUES OF H AND Q AT A CERTAIN TIME LEVEL ARE EXPRESSED DIRECTLY IN TERM OF VALUES OF H AND Q AT PREVIOUS TIME LEVELS.

001 : PLANE AREAS. (M*M)
 AA1 : CROSS-SECTIONAL AREAS (M*M)
 RR1 : HIDRAULIC RADII (M)
 XX1 : SECTION LENGTHS (M)
 HH1 : COMPUTED WATERLEVELS (M)
 VV1 : COMPUTED VELOCITIES (M/S)
 QQ1 : COMPUTED FLOWS (M**3/S)
 SQAPOS: TOTAL POSITIVE FLOW (M**3)
 SQANEG: TOTAL NEGATIVE FLOW (M**3)
 S : VOLUME CHANGE
 VLOED1: TOUWS RIVER FLOW (M**3/S)
 VLOED2: DUIWE RIVER FLOW (M**3/S)
 VLOED3: SPRUIT FLOW (M**3/S)
 HOT : =1, HOTSTART
 START : INITIAL TIME STEP OF PRINTOUT
 FIN : FINAL TIME STEP OF PRINTOUT
 MAXT : MAXIMUM TIME STEP
 IOUT : WRITE INTERVALS
 T1 : SIZE OF TIME STEP
 T : PERIOD (SINE WAVE)
 HSTART: INITIAL WATERLEVEL
 IPRT : TIME STEPS FOR PRINTOUT
 HMIN : WATERLEVELS ON PREVIOUS TIME STEP

PROGRAM TOUWS(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE7,
 TAPE8,TAPE11,TAPE12)
 DIMENSION 001(20,15),AA1(20,15),RR1(20,15),XX1(20),ANGL(20),
 HH1(20),S(20),VV1(20),HMIN(20),SQAPOS(20),SQANEG(20)

```

      ,QQ1(20),XX2(20)
      INTEGER HOT,START,FIN,OPTION
      DIMENSION TR(400),DR(200),SL(120),TITL(8),IPRT(80)
      READ(11,100)(TITL(I),I=1,8)
      READ(11,101)(TR(I),I=1,377)
      READ(11,101)(DR(I),I=1,182)
      READ(11,101)(SL(I),I=1,117)
      READ(5,102)OPTION,HOT,START,FIN
      READ(5,103)MAXT,IOUT,T1,T,HSTART,CHEZY
      READ(5,104)(IPRT(I),I=1,80)

C
C      INITIALIZATION.
C
      DO 600 N=1,15
      DO 601 M=1,15
      OO1(N,M)=0.0
      AA1(N,M)=0.0
      RR1(N,M)=0.0
601  CONTINUE
      XX1(N)=0.0
      XX2(N)=0.0
600  CONTINUE
      NHC=0
      KEER=2
      VL1=0.0
      VL2=0.0
      VL3=0.0
      ISTART=1
      GSTART=-1.5
      PI=3.1415927
      DO 300 N=1,15
      QQ1(N)=0.0
      HH1(N)=HSTART
      HMIN(N)=HH1(N)
      VV1(N)=0.0
      ANGL(N)=0.0
      SQAPOS(N)=0.0
      SQANEG(N)=0.0
300  CONTINUE
      DO 614 I=1,6
614  WRITE(12,613)HH1(1),HH1(9),HH1(11),HH1(13)
      IREADF=8
      CALL DATAIN(IREADF,OO1,AA1,RR1,XX1,XX2)

C
C      HOTSTART
C
      IF(HOT.NE.1)GO TO 2
      REWIND 7
      READ(7,200)ISTART
      IF(EOF(7))6,1,6
1    READ(7,201)(HH1(N),N=1,15)
      READ(7,201)(HMIN(N),N=1,15)
      READ(7,202)(QQ1(N),N=1,15)
      IF(ISTART.EQ.MAXT)GO TO 5
      IF(FIN.LT.ISTART)GO TO 7

C
C
C      WRITE(6,206)(TITL(I),I=1,8),HSTART,MAXT,T1,T
      DO 301 K=ISTART,MAXT
      CALL STROOM(KEER,NHC,VL1,VL2,VL3,OO1,AA1,RR1,XX1,ANGL,QQ1,HH1,
      +S,VV1,HMIN,SQAPOS,SQANEG,GSTART,BREED,DREMPL,START,FIN,IOUT,
      +TR,DR,SL,K,T1,IPRT,XX2,CHEZY,M)
301  CONTINUE

```



```

C
C      HOTSTART
C
      REWIND 7
      WRITE(7,200)MAXT
      WRITE(7,201)(HH1(K),K=1,15)
      WRITE(7,201)(HMIN(I),I=1,15)
      WRITE(7,202)(QQ1(K),K=1,15)
      STOP
5      WRITE(6,203)ISTART
      STOP
6      WRITE(6,204)
      STOP
7      WRITE(6,205)FIN,ISTART
      IF(OPTION.EQ.1)GO TO 2
      STOP
100     FORMAT(8A10)
101     FORMAT(13F6.3)
102     FORMAT(2I1,2I6)
103     FORMAT(2I10,2F10.0,2F10.2)
104     FORMAT(16I5)
613     FORMAT(4F10.3)
206     FORMAT("1",26X,8A10,5(/),
+10X,"***** INITIAL WATERLEVEL",F5.2," M",/,
+10X,"***** MAXIMUM TIMESTEP",I6,/,
+10X,"***** TIME STEP",F5.0," SEC.",/,
+10X,"***** CYCLE",F7.0," SEC.",
+5(/))
200     FORMAT(I8)
201     FORMAT(20F6.2)
202     FORMAT(20F6.0)
203     FORMAT(10X,"***** ISTART = ",I6,1X," = MAXT *****")
204     FORMAT(10X,"***** HOT START SPECIFIED (HOT=1),BUT HOT START FILE EM
+PTY *****")
205     FORMAT(10X,"***** FIN = ",I6," WHICH IS LESS THAN ISTART = ",I6," N
+O OUTPUT WILL BE PRODUCED *****")
      END
C *****
C +      SUBROUTINE DATAIN
C *****
      SUBROUTINE DATAIN(IREADF,OO,AA,RR,XX1,XX2)
      DIMENSION OO(20,15),AA(20,15),RR(20,15),XX1(20),XX2(20)
      DO 300 N=1,15
      READ(IREADF,100)(OO(N,I),I=1,13)
300     CONTINUE
      DO 301 N=1,15
      READ(IREADF,100)(AA(N,I),I=1,13)
301     CONTINUE
      DO 302 N=1,15
      READ(IREADF,101)(RR(N,I),I=1,13)
302     CONTINUE
      READ(IREADF,102)(XX1(N),N=1,14)
      READ(IREADF,102)(XX2(N),N=1,14)
      RETURN
100     FORMAT(8F10.0)
101     FORMAT(16F5.2)
102     FORMAT(11F7.1)
      END
C *****
C +      SUBROUTINE STROOM
C +      HYDRODYNAMIC COMPUTATION
C *****
      SUBROUTINE STROOM(KEER,NHC,VL1,VL2,VL3,OO,AA,RR,XX1,ANGL,QQ1,

```

```

+HH1,S,VV1,HMIN,SQAPOS,SQANEG,GSTART,BREED,DREMP,START,FIN,IOUT,
+TR,DR,SL,K,T1,IPRT,XX2,CHEZY,M)
  DIMENSION OO(20,15),AA(20,15),RR(20,15),XX1(20),ANGL(20),QQ1(20),
+      HH1(20),S(20),VV1(20),HMIN(20),SQAPOS(20),SQANEG(20),
+      TR(150),DR(30),SL(20),IPRT(80),XX2(20)
  INTEGER START,FIN
  CALL FLOOD(KEER,NHC,VL1,VL2,VL3,TR,DR,SL,K)
  QQ1(15)=VL1

```

C
C
C

SUMMATION OF FLOW

```

S(1)=-QQ1(1)
S(2)=QQ1(1)-QQ1(2)
S(3)=QQ1(2)-QQ1(3)
S(4)=QQ1(3)-QQ1(4)
S(5)=QQ1(4)-QQ1(5)-QQ1(14)
S(6)=QQ1(5)-QQ1(6)
S(7)=QQ1(6)-QQ1(7)
S(8)=QQ1(7)-QQ1(8)
S(9)=QQ1(8)-QQ1(9)+VL2
S(10)=QQ1(9)-QQ1(10)
S(11)=QQ1(10)-QQ1(11)
S(12)=QQ1(11)-QQ1(12)+VL3
S(13)=QQ1(12)
S(14)=S(5)
S(15)=QQ1(14)+VL1

```

C
C
C

WATER LEVEL COMPUTATION

```

DO 301 N=1,15
HMIN(N)=HH1(N)
IF(N.EQ.14)HH1(14)=HH1(5)
IF(N.EQ.14)GO TO 301
G=GSTART
DO 302 I=1,12
G=G+0.5
IF((HH1(N)-G).GT.0.5)GO TO 302
HH1(N)=HH1(N)+T1/(OO(N,I)+(OO(N,I+1)-OO(N,I))*(HH1(N)-G)/0.5)
+      *S(N)-0.0000021
GO TO 301
302 CONTINUE
301 CONTINUE

```

C
C
C

FLOW COMPUTATION

```

DO 303 IP=1,15
IF(IP.EQ.13.OR.IP.EQ.15)GO TO 303
WFAC=0.0
G=GSTART
W=(HH1(IP)+HH1(IP+1))/2.0
XX=XX1(IP)
IF(W.GT.2.0)XX=XX2(IP)
DO 304 I=1,12
G=G+0.5
Y=W-G
IF(Y.GT.0.5)GO TO 304
A1=AA(IP,I)+(AA(IP,I+1)-AA(IP,I))*Y/0.5
R1=RR(IP,I)+(RR(IP,I+1)-RR(IP,I))*Y/0.5
IF(R1.GT.0.1.AND.A1.GT.1.0)GO TO 1
QQ1(IP)=0.0
GO TO 303
304 CONTINUE
1 CC=37.5+18.*ALOG10(R1)

```

```

      IF (IP.EQ.5.OR.IP.EQ.7.OR.IP.EQ.9.OR.IP.EQ.10.OR.IP.EQ.12
*      .OR.IP.EQ.6) CC=25.+50.*ALOG10(R1)
      IF (IP.EQ.9.AND.(HH1(9)-HH1(10)).GT.1.0.AND.CC.LT.15.0) CC=15.0
      IF (A1.LE.0.0) GO TO 7
      QQQ1=T1*9.81*A1
      QQQ2=(HH1(IP)-HH1(IP+1))/XX
      QQQ3=QQ1(IP)*ABS(QQ1(IP))/(CC*CC*A1*A1*R1)
      QQQ4=WFAC/(10000.*R1)
      IF (R1.LT.1.0) R1=1.0
      QQQ5=(QQ1(IP)*(HH1(IP)-HMIN(IP)+HH1(IP+1)-HMIN(IP+1)))/R1
      IF (R1.LT.1.0) QQQ5=0.0
      QQA=QQ1(IP)+QQQ5+QQQ1*(QQQ2+QQQ4)
      QQB=QQQ1*QQQ3
      QQ1(IP)=QQA-QQB
      IF (IP.NE.14) GOTO 4
      IF (QQ1(14).GT.0.0) QQ1(14)=0.0
      VV1(IP)=QQ1(IP)/A1
4
303 CONTINUE

```

COMPUTATION OF TOTAL FLOWS

```

C
C
C      DO 305 N=1,15
C      QA=QQ1(N)
C      IF (QA.GT.0.0) SQAPOS(N)=SQAPOS(N)+QA*T1
C      IF (QA.LT.0.0) SQANEG(N)=SQANEG(N)+QA*T1
305 CONTINUE
C      IF (K.GE.START.AND.K.LE.FIN) GO TO 5
C      RETURN
5      DO 306 IPR=1,80
C      IF (IPRT(1).GT.0.AND.K.EQ.IPRT(IPR)) GO TO 6
306 CONTINUE
C      IF (IPRT(1).GT.0) RETURN
C      IF (MOD(K,IOUT).EQ.0) GO TO 6
C      RETURN
6      CALL DATOUT(SQAPOS,SQANEG,K,HH1,QQ1,VV1,T1,M)
C      RETURN
7      WRITE(6,200)
200 FORMAT(10X,"**** FOR SOME REASON A1 IS ZERO ****")
C      STOP
C      END

```

```

C *****
C + SUBROUTINE FLOOD
C + TR : TOUWS RIVER DISCHARGE
C + DR : DUIWE RIVER DISCHARGE
C + SL : BO-LANGVLEI SPRUIT DISCHARGE
C *****

```

```

      SUBROUTINE FLOOD(KEER,NHC,VL1,VL2,VL3,TR,DR,SL,K)
      DIMENSION TR(400),DR(200),SL(120)
      IT1=30
      IF (KEER.GT.376) GO TO 3
      IF ((K/IT1)*IT1.EQ.K) KEER=KEER+1
      NHC=NHC+1
      IF (NHC.EQ.IT1) NHC=0
      IF (KEER.GT.116) GO TO 1
      VL3=SL(KEER-1)+(SL(KEER)-SL(KEER-1))*FLOAT(NHC)/30.0
1      IF (KEER.GT.181) GO TO 2
      VL2=DR(KEER-1)+(DR(KEER)-DR(KEER-1))*FLOAT(NHC)/30.0
2      VL1=TR(KEER-1)+(TR(KEER)-TR(KEER-1))*FLOAT(NHC)/30.0
3      RETURN
      END

```

```

C *****
C + SUBROUTINE DATOUT
C *****

```

```

SUBROUTINE DATOUT(SQAPOS,SQANEG,K,HH1,QQ1,VV1,T1,M)
DIMENSION SQAPOS(20),SQANEG(20),HH1(20),QQ1(20),VV1(20)
TIME=K*T1
IHRS=TIME/3600.
MNTE=(TIME-IHRS*3600.)/60.
ISEC=TIME-IHRS*3600.-MNTE*60.
C   WRITE(6,200)K,IHRS,MNTE,ISEC
200  FORMAT(/,"  NUMBER OF TIMESTEP = "I8,"  TIME = ",
+I4," HR.",I4," MIN.",I4," SEC.")
C   WRITE(6,202)(N,N=1,15),(SQAPOS(N),N=1,15),(SQANEG(N),N=1,15)
202  FORMAT(1X,70(" "),/," SECTIONS ",4X,I2,14(6X,I2),
+/, " POS FLOW ",15(F8.0),
+/, " NEG FLOW ",15(F8.0),/)
C   WRITE(6,203)
203  FORMAT(8X,"MOUTH",19X,"SPLIT",14X,"ONDER-LANG",6X,
+ "BO-LANG      RONDE")
      WRITE(12,613)HH1(1),HH1(9),HH1(11),HH1(13)
613  FORMAT(4F10.3)
C   WRITE(6,204)(HH1(I),I=1,15)
204  FORMAT("  H = ",(20F6.2))
C   WRITE(6,205)(QQ1(I),I=1,15)
205  FORMAT("  Q = ",(20F6.0))
C   WRITE(6,206)(VV1(I),I=1,15)
206  FORMAT("  V = ",(20F6.2))
      RETURN
      END

```

APPENDIX B.2

EXTENSIONS TO THE ORIGINAL PROGRAM FOR THE RIGID AND MOVABLE
BED SILLS AT THE RIVER MOUTH


```

C *****
C *
C *      WILDERNESS ONE-DIMENSIONAL EXPLICIT MODEL
C *
C *      001      : PLANE AREAS. (M*M)
C *      AA1      : CROSS-SECTIONAL AREAS (M*M)
C *      RR1      : HIDRAULIC RADII (M)
C *      XX1      : SECTION LENGTHS (M)
C *      HH1      : COMPUTED WATERLEVELS (M)
C *      VV1      : COMPUTED VELOCITIES (M/S)
C *      QQ1      : COMPUTED FLOWS (M**3/S)
C *      SQAPOS: TOTAL POSITIVE FLOW (M**3)
C *      SQANEG: TOTAL NEGATIVE FLOW (M**3)
C *      S        : VOLUME CHANGE
C *      VLOED1: TOUWS RIVER FLOW (M**3/S)
C *      VLOED2: DUIWE RIVER FLOW (M**3/S)
C *      VLOED3: SPRUIT FLOW (M**3/S)
C *      HOT      : =1, HOTSTART
C *      START    : INITIAL TIME STEP OF PRINTOUT
C *      FIN      : FINAL TIME STEP OF PRINTOUT
C *      MAXT     : MAXIMUM TIME STEP
C *      IOUT     : WRITE INTERVALS
C *      T1       : SIZE OF TIME STEP
C *      T        : PERIOD (SINE WAVE)
C *      HSTART   : INITIAL WATERLEVEL
C *      IPRT     : TIME STEPS FOR PRINTOUT
C *      HMIN     : WATERLEVELS ON PREVIOUS TIME STEP
C *      SILL     : SILL HEIGHT (M)
C *      SLE      : LENGTH OF SILL (M)
C *      B        : WIDTH OF SILL (M)
C *****
C
C      PROGRAM TOUWS(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE7,
C * TAPE8,TAPE11,TAPE12)
C      COMMON QQ,B,SLE,SILL,CD
C      DIMENSION 001(20,15),AA1(20,15),RR1(20,15),XX1(20),ANGL(20),
C *          HH1(20),S(20),VV1(20),HMIN(20),SQAPOS(20),SQANEG(20)
C *          ,QQ1(20),XX2(20)
C      INTEGER HOT,START,FIN,OPTION
C      DIMENSION TR(364),DR(210),SL(169),TITL(8),IPRT(80)
C      READ(11,100)(TITL(I),I=1,8)
C      READ(11,101)(TR(I),I=1,364)
C      READ(11,101)(DR(I),I=1,208)
C      READ(11,101)(SL(I),I=1,169)
C      READ(5,102)OPTION,HOT,START,FIN
C      READ(5,103)MAXT,IOUT,T1,T,HSTART,CHEZY,SILL,B,SLE,CD
C      READ(5,104)(IPRT(I),I=1,80)
C
C      INITIALIZATION.
C
C      DO 600 N=1,15
C      DO 601 M=1,15
C      001(N,M)=0.0
C      AA1(N,M)=0.0
C      RR1(N,M)=0.0
601  CONTINUE
C      XX1(N)=0.0
C      XX2(N)=0.0
600  CONTINUE
C      QQ=0.0
C      NHC=0
C      KEER=2
C      VL1=0.0

```

```

VL2=0.0
VL3=0.0
ISTART=1
GSTART=-1.5
PI=3.1415927
DO 300 N=1,15
  QQ1(N)=0.0
  HH1(N)=HSTART
  HMIN(N)=HH1(N)
  VV1(N)=0.0
  ANGL(N)=0.0
  SQAPOS(N)=0.0
  SQANEG(N)=0.0
300  CONTINUE
DO 614 I=1,6
  614  WRITE(12,613)HH1(1),HH1(9),HH1(11),HH1(13)
      IREADF=8
      CALL DATAIN(IREADF,001,AA1,RR1,XX1,XX2)
C
C      HOTSTART
C
      IF(HOT.NE.1)GO TO 2
      REWIND 7
      READ(7,200)ISTART
      IF(EOF(7))6,1,6
1      READ(7,201)(HH1(N),N=1,15)
      READ(7,201)(HMIN(N),N=1,15)
      READ(7,202)(QQ1(N),N=1,15)
      IF(ISTART.EQ.MAXT)GO TO 5
      IF(FIN.LT.ISTART)GO TO 7
C
C
2      WRITE(6,206)(TITL(I),I=1,8),HSTART,MAXT,T1,T
      DO 301 K=ISTART,MAXT
      CALL STROOM(KEER,NHC,VL1,VL2,VL3,001,AA1,RR1,XX1,ANGL,QQ1,HH1,
+ S,VV1,HMIN,SQAPOS,SQANEG,GSTART,BREED,DREMPL,START,FIN,IOUT,
+ TR,DR,SL,K,T1,IPRT,XX2,CHEZY,M)
301  CONTINUE
C
C      HOTSTART
C
      REWIND 7
      WRITE(7,200)MAXT
      WRITE(7,201)(HH1(K),K=1,15)
      WRITE(7,201)(HMIN(I),I=1,15)
      WRITE(7,202)(QQ1(K),K=1,15)
      STOP
5      WRITE(6,203)ISTART
      STOP
6      WRITE(6,204)
      STOP
7      WRITE(6,205)FIN,ISTART
      IF(OPTION.EQ.1)GO TO 2
      STOP
100  FORMAT(8A10)
101  FORMAT(13F6.3)
102  FORMAT(2I1,2I6)
103  FORMAT(2I5,8F8.0)
104  FORMAT(16I5)
  613  FORMAT(4F10.3)
206  FORMAT("1",26X,8A10,5(/),
+ 10X,"***** INITIAL WATERLEVEL",F5.2," M",/,
+ 10X,"***** MAXIMUM TIMESTEP",I6,/,

```

```

+10X,"***** TIME STEP",F5.0," SEC.",/,
+10X,"***** CYCLE",F7.0," SEC.",
+5(/))
200  FORMAT(I8)
201  FORMAT(20F6.2)
202  FORMAT(20F6.0)
203  FORMAT(10X,"**** ISTART = ",I6,1X," = MAXT ****")
204  FORMAT(10X,"**** HOT START SPECIFIED (HOT=1),BUT HOT START FILE EM
+PTY ****")
205  FORMAT(10X,"**** FIN = ",I6," WHICH IS LESS THAN ISTART = ",I6," N
+O OUTPUT WILL BE PRODUCED ****")
      END
C  ++++++
C  +      SUBROUTINE DATAIN
C  ++++++
      SUBROUTINE DATAIN(IREADF,00,AA,RR,XX1,XX2)
      DIMENSION 00(20,15),AA(20,15),RR(20,15),XX1(20),XX2(20)
      DO 300 N=1,15
      READ(IREADF,100)(00(N,I),I=1,13)
300  CONTINUE
      DO 301 N=1,15
      READ(IREADF,100)(AA(N,I),I=1,13)
301  CONTINUE
      DO 302 N=1,15
      READ(IREADF,101)(RR(N,I),I=1,13)
302  CONTINUE
      READ(IREADF,102)(XX1(N),N=1,14)
      READ(IREADF,102)(XX2(N),N=1,14)
      RETURN
100  FORMAT(8F10.0)
101  FORMAT(16F5.2)
102  FORMAT(11F7.1)
      END
C  ++++++
C  +      SUBROUTINE STROOM
C  +      HYDRODYNAMIC COMPUTATION
C  ++++++
      SUBROUTINE STROOM(KEER,NHC,VL1,VL2,VL3,00,AA,RR,XX1,ANGL,QQ1,
+HH1,S,VV1,HMIN,SQAPOS,SQANEG,GSTART,BREED,DREMP,START,FIN,IOUT,
+TR,DR,SL,K,T1,IPRT,XX2,CHEZY,M)
      COMMON QQ,B,SLE,SILL,CD
      DIMENSION 00(20,15),AA(20,15),RR(20,15),XX1(20),ANGL(20),QQ1(20),
+      HH1(20),S(20),VV1(20),HMIN(20),SQAPOS(20),SQANEG(20),
+      TR(364),DR(210),SL(169),IPRT(80),XX2(20)
      INTEGER START,FIN
      CALL FLOOD(KEER,NHC,VL1,VL2,VL3,TR,DR,SL,K)
      QQ1(15)=-VL1
C
C      SUMMATION OF FLOW
C
      S(1)=-QQ1(1)
      IF(HH1(1).GT.SILL+0.01)S(1)=-QQ-QQ1(1)
      S(2)=QQ1(1)-QQ1(2)
      S(3)=QQ1(2)-QQ1(3)
      S(4)=QQ1(3)-QQ1(4)
      S(5)=QQ1(4)-QQ1(5)-QQ1(14)
      S(6)=QQ1(5)-QQ1(6)
      S(7)=QQ1(6)-QQ1(7)
      S(8)=QQ1(7)-QQ1(8)
      S(9)=QQ1(8)-QQ1(9)+VL2
      S(10)=QQ1(9)-QQ1(10)
      S(11)=QQ1(10)-QQ1(11)
      S(12)=QQ1(11)-QQ1(12)+VL3

```

S(13)=QQ1(12)
 S(14)=S(5)
 S(15)=QQ1(14)+VL1

WATER LEVEL COMPUTATION

DO 301 N=1,15
 HMIN(N)=HH1(N)
 IF(N.EQ.14)HH1(14)=HH1(5)
 IF(N.EQ.14)GO TO 301
 G=GSTART
 DO 302 I=1,12
 G=G+0.5
 IF((HH1(N)-G).GT.0.5)GO TO 302
 HH1(N)=HH1(N)+T1/(OO(N,I)+(OO(N,I+1)-OO(N,I))*(HH1(N)-G)/0.5)
 * S(N)-0.0000021
 GO TO 301
 302 CONTINUE
 301 CONTINUE

FLOW COMPUTATION

DO 303 IP=1,15
 IF(IP.EQ.13.OR.IP.EQ.15)GO TO 303
 WFAC=0.0
 G=GSTART
 W=(HH1(IP)+HH1(IP+1))/2.0
 XX=XX1(IP)
 IF(W.GT.2.0)XX=XX2(IP)
 DO 304 I=1,12
 G=G+0.5
 Y=W-G
 IF(Y.GT.0.5)GO TO 304
 A1=AA(IP,I)+(AA(IP,I+1)-AA(IP,I))*Y/0.5
 R1=RR(IP,I)+(RR(IP,I+1)-RR(IP,I))*Y/0.5
 IF(R1.GT.0.1.AND.A1.GT.1.0)GO TO 1
 QQ1(IP)=0.0
 GO TO 303
 304 CONTINUE
 1 CC=37.5+18.*ALOG10(R1)
 IF(IP.EQ.5.OR.IP.EQ.7.OR.IP.EQ.9.OR.IP.EQ.10.OR.IP.EQ.12
 * .OR.IP.EQ.6)CC=25.+50.*ALOG10(R1)
 IF(IP.EQ.9.AND.(HH1(9)-HH1(10)).GT.1.0.AND.CC.LT.15.0)CC=15.0
 IF(A1.LE.0.0)GO TO 7
 QQQ1=T1*9.81*A1
 QQQ2=(HH1(IP)-HH1(IP+1))/XX
 QQQ3=QQ1(IP)*ABS(QQ1(IP))/(CC*CC*A1*A1*R1)
 QQQ4=WFAC/(10000.*R1)
 IF(R1.LT.1.0)R1=1.0
 QQQ5=(QQ1(IP)*(HH1(IP)-HMIN(IP)+HH1(IP+1)-HMIN(IP+1)))/R1
 IF(R1.LT.1.0)QQQ5=0.0
 QQA=QQ1(IP)+QQQ5+QQQ1*(QQQ2+QQQ4)
 QQB=QQQ1*QQQ3
 QQ1(IP)=QQA-QQB
 IF(IP.NE.14)GOTO 4
 IF(QQ1(14).GT.0.0)QQ1(14)=0.0
 4 VV1(IP)=QQ1(IP)/A1
 303 CONTINUE
 IF(HH1(1).LE.SILL+0.01)QQ=0.0
 IF(HH1(1).LE.SILL+0.01)GOTO 773
 HH=HH1(1)-SILL
 HSILL=2.*HH/3.
 RSILL=HSILL*B/(2.*HSILL+B)

```

CSILL=37.5+18*ALOG10(RSILL)
GSILL=1.0/9.81
ASILL=2.0/(SQRT(GSILL*0.5+SLE/(CSILL*CSILL*RSILL)))*8
BSILL=(VV1(1)*VV1(1)*GSILL/6.0+HH/3.0)**1.5
QQ=ASILL*BSILL
IF(SILL.LE.0.4)GOTO 773
VSILL=QQ/(8*HH)
SILMIN=23.4*VSILL**5*T1/(CSILL**3*SLE)

```

```
IF(B.LE.90.0)B=B+0.1111
```

```
SILL=SILL-SILMIN
```

```
773 CONTINUE
```

```
IF(MOD(K,20).EQ.0)WRITE(6,775)SILL,VSILL,K
+ ,HH1(1),HH1(9),HH1(11),HH1(13)
```

```
775 FORMAT(2F10.5,I10,4F10.4)
```

```
C IF(MOD(K,20).EQ.0)WRITE(6,776)HH1(6),HH1(7),VV1(6),QQ1(6)
```

```
776 FORMAT(4E10.4)
```

```
C
```

```
C
```

```
C
```

COMPUTATION OF TOTAL FLOWS

```
DO 305 N=1,15
```

```
QA=QQ1(N)
```

```
IF(QA.GT.0.0)SQAPOS(N)=SQAPOS(N)+QA*T1
```

```
IF(QA.LT.0.0)SQANEG(N)=SQANEG(N)+QA*T1
```

```
305 CONTINUE
```

```
IF(K.GE.START.AND.K.LE.FIN)GO TO 5
```

```
RETURN
```

```
5 DO 306 IPR=1,80
```

```
IF(IPRT(1).GT.0.AND.K.EQ.IPRT(IPR))GO TO 6
```

```
306 CONTINUE
```

```
IF(IPRT(1).GT.0)RETURN
```

```
IF(MOD(K,IOUT).EQ.0)GO TO 6
```

```
RETURN
```

```
6 CALL DATOUT(SQAPOS,SQANEG,K,HH1,QQ1,VV1,T1,M)
```

```
RETURN
```

```
7 WRITE(6,200)
```

```
200 FORMAT(10X,"**** FOR SOME REASON A1 IS ZERO ****")
```

```
STOP
```

```
END
```

```
C
```

```
C
```

```
C
```

```
C
```

```
C
```

```
C
```

```

*****
+ SUBROUTINE FLOOD
+ TR : TOUWS RIVER DISCHARGE
+ DR : DUIWE RIVER DISCHARGE
+ SL : BO-LANGVLEI SPRUIT DISCHARGE
*****

```

```
SUBROUTINE FLOOD(KEER,NHC,VL1,VL2,VL3,TR,DR,SL,K)
```

```
DIMENSION TR(364),DR(210),SL(169)
```

```
IT1=60
```

```
IF(KEER.GT.364)GO TO 3
```

```
IF((K/IT1)*IT1.EQ.K)KEER=KEER+1
```

```
NHC=NHC+1
```

```
IF(NHC.EQ.IT1)NHC=0
```

```
IF(KEER.GT.169)GO TO 1
```

```
1 VL3=SL(KEER-1)+(SL(KEER)-SL(KEER-1))*FLOAT(NHC)/60.0
```

```
2 IF(KEER.GT.208)GO TO 2
```

```
3 VL2=DR(KEER-1)+(DR(KEER)-DR(KEER-1))*FLOAT(NHC)/60.0
```

```
4 VL1=TR(KEER-1)+(TR(KEER)-TR(KEER-1))*FLOAT(NHC)/60.0
```

```
5 RETURN
```

```
END
```

```
C
```

```
C
```

```
C
```

```

*****
+ SUBROUTINE DATOUT
*****

```

```
SUBROUTINE DATOUT(SQAPOS,SQANEG,K,HH1,QQ1,VV1,T1,M)
```



```

DIMENSION SQAPOS(20),SQANEG(20),HH1(20),QQ1(20),VV1(20)
TIME=K*T1
IHRS=TIME/3600.
MNTE=(TIME-IHRS*3600.)/60.
ISEC=TIME-IHRS*3600.-MNTE*60.
C   WRITE(6,200)K,IHRS,MNTE,ISEC
200  FORMAT(/,"  NUMBER OF TIMESTEP = "I8,"  TIME = ",
+I4," HR.",I4," MIN.",I4," SEC.")
C   WRITE(6,202)(N,N=1,15),(SQAPOS(N),N=1,15),(SQANEG(N),N=1,15)
202  FORMAT(1X,70(" "),/," SECTIONS ",4X,I2,14(6X,I2),
+/, " POS FLOW ",15(F8.0),
+/, " NEG FLOW ",15(F8.0),/)
C   WRITE(6,203)
203  FORMAT(8X,"MOUTH",19X,"SPLIT",14X,"ONDER-LANG",6X,
* "BO-LANG      RONDE")
WRITE(12,613)HH1(1),HH1(9),HH1(11),HH1(13)
613  FORMAT(4F10.3)
C   WRITE(6,204)(HH1(I),I=1,15)
204  FORMAT("  H = ",(20F6.2))
C   WRITE(6,205)(QQ1(I),I=1,15)
205  FORMAT("  Q = ",(20F6.0))
C   WRITE(6,206)(VV1(I),I=1,15)
206  FORMAT("  V = ",(20F6.2))
RETURN
END

```

APPENDIX B.3

SUPPORTING PROGRAMS: PLOT PROGRAM FOR WATER LEVEL HISTORIES

```
PROGRAM WILPLOT(INPUT,OUTPUT,KT,DA1,DA2,TAPE61=INPUT,TAPE62=OUTPUT
*,TAPE10=KT,TAPE11=DA1,TAPE12=DA2)
```

```
CALL STANFIG
```

```
CALL KAART
```

```
CALL PLOT(-1.38,-1.18,-3)
```

```
CALL FACTOR(0.394)
```

```
C CALL SKRIF
```

```
K=11
```

```
CALL GRAPH(K)
```

```
CALL PLOT(0.0,12.0,-3)
```

```
K=12
```

```
CALL GRAPH(K)
```

```
CALL PLOT(12.0,-16.0,999)
```

```
END
```

```
SUBROUTINE SKRIF
```

```
CALL SYMBOL(-2.8,2.60,0.20,11,90.0,-1)
```

```
CALL SYMBOL(-2.5,2.0,0.20,"MAX. FLOOD",90.0,10)
```

```
CALL SYMBOL(-2.2,2.0,0.20,"6.28 CUMEC",90.0,10)
```

```
CALL SYMBOL(-1.5,4.10,0.20,11,90.0,-1)
```

```
CALL SYMBOL(-1.2,3.50,0.20,"MAX. FLOOD",90.0,10)
```

```
CALL SYMBOL(-0.9,3.50,0.20,"5.68 CUMEC",90.0,10)
```

```
RETURN
```

```
END
```

```
C*****
```

```
C*
```

```
C*          PLOTROUTINE VIR TITELBLOK
```

```
C*
```

```
C*****
```

```
SUBROUTINE STANFIG
```

```
DIMENSION PROJ(3),TITL(5),TITE(5)
```

```
DIMENSION DAT(1)
```

```
READ (10,100) PROJ
```

```
READ (10,110) NST
```

```
READ (10,120) XTIT,YTIT,NOGT
```

```
READ (10,100) TITL
```

```
IF (NOGT .EQ. 0) GO TO 50
```

```
READ (10,120) XTIS,YTIS
```

```
READ (10,100) TITE
```

```
50 READ (10,130) FIGNO
```

```
100 FORMAT (5A10)
```

```
110 FORMAT (I2)
```

```
120 FORMAT (2F10.5,I2)
```

```
130 FORMAT (1X,A3)
```

```
XX0 = 0.
```

```
XX1 = 1.
```

```
XX2 = 2.5
```

```
XX4 = 6.
```

```
XX5 = 0.28
```

```
XX6 = 0.46
```

```
XX7 = 0.64
```

```
XX8 = 0.75
```

```
XX9 = 0.82
```

```
XX10 = 1.25
```

```
XX11 = 11.2032
```

```
XX12 = 0.0625
```

```
XX13 = 0.1875
```

```
XX14 = 6.3125
```

```
XX15 = 7.1875
```

```
XX16 = 0.03125
```

```
XX17 = 0.84375
```

```
XX18 = 2.
```

```
XX19 = 6.3
```

```
XX20 = 0.35
```

```

ALF1 = 0.
ALF2 = -90.
AH1 = 0.0625
AH2 = 0.09375
AH3 = 0.125
AH4 = 0.14
IF (NOGT .NE. 0) AH4 = AH3
CALL PLOTS (-2.,-200.,62)
CALL NEWPEN(1)

```

```

C
C***
C*** TREK DIE RAAMWERK VIR DIE BLADSY
C***

```

```

***
***
***

```

```

IF (NST .EQ. 1) GO TO 10
CALL PLOT (XX0,XX0,3)
CALL PLOT (XX15,XX0,2)
CALL PLOT (XX15,XX11,2)
CALL PLOT (XX0,XX11,2)
CALL PLOT (XX0,XX0,2)
CALL PLOT (XX0,XX1,3)
CALL PLOT (XX15,XX1,2)
CALL PLOT (XX15,XX13,3)
CALL PLOT (XX0,XX13,2)
CALL PLOT (XX10,XX13,3)
CALL PLOT (XX10,XX1,2)
CALL PLOT (XX4,XX1,3)
CALL PLOT (XX4,XX13,2)

```

```

C***
C*** PLOT OPSKRIF
C***

```

```

***
***
***

```

```

C CALL NEWPEN (2)
  XDAT=7*AH1
  CALL DATE(A)
  DAT(1)=A
  CALL SYMBOL (XX12,XX5,AH1,"REF. : " ,ALF1,17)
  CALL SYMBOL (XX12,XX6,AH1,"DATE : " ,ALF1,7)
  CALL SYMBOL (XDAT,XX6,AH1,DAT,ALF1,10)
  CALL SYMBOL (XX12,XX7,AH1,"CHECKED : WAMB",ALF1,14)
  CALL SYMBOL (XX12,XX9,AH1,"TRACED : COMLOT",ALF1,16)
  CALL SYMBOL (XX18,XX16,AH2,"NATIONAL RESEARCH INSTITUTE FOR OCEANO
1 LOGY",ALF1,42)
  CALL SYMBOL (XX2,XX17,AH2,PROJ,ALF1,30)
  CALL SYMBOL (XTIT,YTIT,AH4,TITL,ALF1,40)
  IF (NOGT .EQ. 0) GO TO 200
  CALL SYMBOL (XTIS,YTIS,AH4,TITE,ALF1,40)
200 CALL SYMBOL (XX14,XX8,AH3,"FIGURE",ALF1,6)
  CALL SYMBOL (XX19,XX20,AH4,FIGNO,ALF1,3)
  GO TO 20

```

```

C***
C*** TREK DIE RAAMWERK VIR DIE BLADSY
C***

```

```

***
***
***

```

```

10 CALL PLOT (XX0,XX0,3)
  CALL PLOT (XX11,XX0,2)
  CALL PLOT (XX11,XX15,2)
  CALL PLOT (XX0,XX15,2)
  CALL PLOT (XX0,XX0,2)
  CALL PLOT (XX1,XX0,3)
  CALL PLOT (XX1,XX15,2)
  CALL PLOT (XX13,XX15,3)
  CALL PLOT (XX13,XX0,2)
  CALL PLOT (XX13,XX10,3)
  CALL PLOT (XX1,XX10,2)
  CALL PLOT (XX1,XX4,3)
  CALL PLOT (XX13,XX4,2)

```

CALL PLOT (XX0,XX15,-3)

C***

C***

C***

C

CALL NEWPEN (2)

CALL SYMBOL (XX5,-XX12,AH1,"REF. : C/SEA 8040",ALF2,17)

CALL SYMBOL (XX6,-XX12,AH1,"DATE : 1980-08-30",ALF2,17)

CALL SYMBOL (XX7,-XX12,AH1,"CHECKED : J.M.",ALF2,14)

CALL SYMBOL (XX9,-XX12,AH1,"TRACED : COMLOT",ALF2,16)

CALL SYMBOL (XX16,-XX18,AH2,"NATIONAL RESEARCH INSTITUTE FOR OCEAN
IOLOGY",ALF2,42)

CALL SYMBOL (XX17,-XX2,AH2,PROJ,ALF2,20)

CALL SYMBOL (XTIT,YTIT,AH4,TITL,ALF2,40)

IF (NOGT .EQ. 0) GO TO 250

CALL SYMBOL (XTIS,YTIS,AH4,TITE,ALF2,40)

250 CALL SYMBOL (XX8,-XX14,AH3,"FIGURE",ALF2,6)

CALL SYMBOL (XX20,-XX19,AH4,FIGNO,ALF2,3)

20 RETURN

END

C*****

C*

*

C*

TEKEN KAART VAN WILDERNIS

*

C*

SKAAL 1:77440

*

C*

*

C*****

SUBROUTINE KAART

DIMENSION X(120),Y(120)

READ(10,1)(X(I),Y(I),I=1,115)

1 FORMAT(2F5.2)

CALL PLOT(5.51,2.76,-3)

CALL PLOT(X(1),Y(1),3)

DO 2 I=2,115

CALL PLOT(X(I),Y(I),2)

2 CONTINUE

CALL PLOT(0.85,3.15,3)

CALL PLOT(0.91,3.23,2)

CALL PLOT(0.91,3.31,2)

CALL PLOT(0.85,3.39,2)

CALL PLOT(0.75,3.27,2)

CALL PLOT(0.77,3.19,2)

CALL PLOT(0.85,3.15,2)

CALL SYMBOL(0.91,0.39,0.08,4,90.0,-1)

CALL SYMBOL(0.83,0.20,0.06,"WILDERNESS",90.0,10)

CALL SYMBOL(0.3,2.05,0.06,"TOUWS RIVER",90.0,11)

CALL SYMBOL(1.24,3.50,0.08,1,90.0,-1)

CALL SYMBOL(1.46,3.50,0.06,"ONDER-LANGVLEI",90.0,14)

CALL SYMBOL(0.53,5.22,0.08,2,90.0,-1)

CALL SYMBOL(0.35,5.16,0.06,"BO-LANGVLEI",90.0,11)

CALL SYMBOL(0.91,6.81,0.08,11,90.0,-1)

CALL SYMBOL(0.98,6.93,0.06,"RONDEVLEI",90.0,9)

CALL SYMBOL(1.46,1.57,0.06,"SCALE 1:177440",90.0,14)

CALL SYMBOL(0.98,1.89,0.06,11,90.0,-1)

CALL PLOT(0.55,1.89,2)

CALL SYMBOL(0.55,1.89,0.06,11,90.0,-1)

CALL SYMBOL(0.55,1.97,0.06,"5",90.0,1)

CALL SYMBOL(1.14,2.52,0.06,11,90.0,-1)

CALL PLOT(0.71,2.76,2)

CALL SYMBOL(0.71,2.76,0.06,11,90.0,-1)

CALL SYMBOL(0.71,2.83,0.06,"7",90.0,1)

CALL SYMBOL(0.87,3.90,0.06,11,90.0,-1)

CALL PLOT(0.43,3.90,2)

CALL SYMBOL(0.43,3.90,0.06,11,90.0,-1)

CALL SYMBOL(0.43,3.98,0.06,"9",90.0,1)


```

CALL SYMBOL(0.91,4.33,0.06,11,90.0,-1)
CALL PLOT(0.24,4.33,2)
CALL SYMBOL(0.24,4.33,0.06,11,90.0,-1)
CALL SYMBOL(0.24,4.41,0.06,"10",90.0,2)
RETURN
END

```

```

C*****
C*
C*          GRAFIEKE VAN WATERHOOGTES
C*          BY1,BY2,BY3 : BESKRYWING VAN GRAFIEK
C*          IBY11       : AANTAL KARAKTERS IN BY1
C*          IBY22       : " " " BY2
C*          IBY33       : " " " BY3
C*          YSTART      : BEGINWAARDE Y-AS
C*          YINC        : INKREMENT Y-AS
C*
C*****

```

```

SUBROUTINE GRAPH(K)
  DIMENSION X(110),Y1(110),Y2(110),Y3(110),Y4(110),BY1(7),BY2(7),
+ BY3(7)
  READ(10,2)BY1,BY2,BY3
  2  FORMAT(7A10)
  READ(10,3)MAX,IBY11,IBY22,IBY33
  3  FORMAT(4I5)
  READ(10,4)YSTART,YINC
  4  FORMAT(2F10.2)
  X(1)=0.0
  DO 5 I=2,MAX
  X(I)=X(I-1)+6.0
  5  CONTINUE
  READ(K,6)(Y1(I),Y2(I),Y3(I),Y4(I),I=1,MAX)
  6  FORMAT(4F10.3)
  DO 99 I=1,MAX
  Y1(I)=-Y1(I)
  Y2(I)=-Y2(I)
  Y3(I)=-Y3(I)
  Y4(I)=-Y4(I)
  99 CONTINUE
  I=MAX+1
  X(I)=0.0
  Y1(I)=-YSTART
  Y2(I)=-YSTART
  Y3(I)=-YSTART
  Y4(I)=-YSTART
  I=MAX+2
  X(I)=40.0
  Y1(I)=YINC
  Y2(I)=YINC
  Y3(I)=YINC
  Y4(I)=YINC
  CALL SYMBOL(0.9,4.0,0.15,"TIME (HOURS)",90.0,12)
  CALL SYMBOL(-3.5,-0.8,0.15,"WATER LEVEL (M)",180.0,15)
  CALL SYMBOL(1.5,0.0,0.20,BY1,90.0,IBY11)
  CALL SYMBOL(2.0,0.0,0.20,BY2,90.0,IBY22)
  CALL SYMBOL(2.5,0.0,0.20,BY3,90.0,IBY33)
C  CALL NEWPEN(3)
  CALL LINE(Y1,X,MAX,1,1,4)
  CALL LINE(Y2,X,MAX,1,1,1)
  CALL LINE(Y3,X,MAX,1,1,2)
  CALL LINE(Y4,X,MAX,1,1,11)
C  CALL NEWPEN(1)
  XCO=0.0
  DO 7 I=1,5

```

```

CALL PLOT(XCO,0.0,3)
CALL PLOT(XCO,10.0,2)
XCO=XCO-1.0
CALL PLOT(XCO,10.0,3)
CALL PLOT(XCO,0.0,2)
XCO=XCO-1.0
7  CONTINUE
CALL PLOT(XCO,0.0,3)
CALL PLOT(XCO,10.0,2)
YCO=0.0
DO 8 I=1,5
CALL PLOT(0.0,YCO,3)
CALL PLOT(-10.0,YCO,2)
YCO=YCO+1.0
CALL PLOT(-10.0,YCO,3)
CALL PLOT(0.0,YCO,2)
YCO=YCO+1.0
8  CONTINUE
CALL PLOT(0.0,YCO,3)
CALL PLOT(-10.0,YCO,2)
CALL SYMBOL(0.3,-0.1,0.15,"0",90.0,1)
CALL SYMBOL(0.3,0.85,0.15,"40",90.0,2)
CALL SYMBOL(0.3,1.85,0.15,"80",90.0,2)
CALL SYMBOL(0.3,2.80,0.15,"120",90.0,3)
CALL SYMBOL(0.3,3.80,0.15,"160",90.0,3)
CALL SYMBOL(0.3,4.80,0.15,"200",90.0,3)
CALL SYMBOL(0.3,5.80,0.15,"240",90.0,3)
CALL SYMBOL(0.3,6.80,0.15,"280",90.0,3)
CALL SYMBOL(0.3,7.80,0.15,"320",90.0,3)
CALL SYMBOL(0.3,8.80,0.15,"360",90.0,3)
CALL SYMBOL(0.3,9.80,0.15,"400",90.0,3)
CALL SYMBOL(0.05,-0.4,0.15,"0.6",90.0,3)
CALL SYMBOL(-0.95,-0.4,0.15,"0.8",90.0,3)
CALL SYMBOL(-1.95,-0.4,0.15,"1.0",90.0,3)
CALL SYMBOL(-2.95,-0.4,0.15,"1.2",90.0,3)
CALL SYMBOL(-3.95,-0.4,0.15,"1.4",90.0,3)
CALL SYMBOL(-4.95,-0.4,0.15,"1.6",90.0,3)
CALL SYMBOL(-5.95,-0.4,0.15,"1.8",90.0,3)
CALL SYMBOL(-6.95,-0.4,0.15,"2.0",90.0,3)
CALL SYMBOL(-7.95,-0.4,0.15,"2.2",90.0,3)
CALL SYMBOL(-8.95,-0.4,0.15,"2.4",90.0,3)
CALL SYMBOL(-9.95,-0.4,0.15,"2.6",90.0,3)
RETURN
END

```

14.13.16.UCLP, AACON14 , 1.496KLNS.