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HYDRAULIC STUDIES FOR LIDDELL POWER STATION
VOL. I: HUNTER RIVER INTAKE BASIC DATA

by

K K Lai, K C Yong and R Hattersley

Research Report No. 110
April 1969

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The University of New South Wales

WATER RESEARCH LABORATORY

Hydraulic Studies for Liddell Power Station

Vol. I : Hunter River Intake
Basic Data

by K.K. Lai K.C Yong R.T. Hattersley

Report No. 110

Final Report to the Electricity Commission of New South Wales

April 1969.

PREFACE

The material contained in this report is to be read in conjunction with Water Research Laboratory Report No. 110, Vol.II, 'River Pumping Station' and it summarises extensive investigations both in the field and by the use of hydraulic models whereby a basis of design for the river works for Liddell Power Station was formulated. Planning and detailed supervision of the work at the Water Research Laboratory was carried out by Mrs. D.M. Stone, Projects Officer under the general direction of the undersigned. Because of the extent of the investigation, much of the detail is contained in progress reports to the Electricity Commission of New South Wales.

It is worth recording that although the Hunter Valley is one of the most developed rural areas in N.S.W., the lack of essential basic data concerning the Hunter River was immediately apparent in the early stages of these engineering studies. Much of the credit for overcoming these deficiencies lies with the Engineering staff of the Electricity Commission whose assistance is gratefully appreciated. In particular the close co-ordination achieved by Messrs. K.S. Watson and C.G. Coulter deserves special acknowledgement.

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Officer-in-Charge,
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Summary

This report embodies the result of an investigation of the Hunter River pump intake for the Liddell Power Station.

The two main problems associated with the operation of an intake on the Hunter River involve river stage and the nature of the bed material.

The flow in the Hunter is often less than 100 c.f.s. and yet can be as high as 400,000 c.f.s. The intake must therefore be capable of operating at a very low stage while being safe against high flows and stages which approach 50 feet.

The alluvial bed of the river at the pumping station is composed of fine loose sand overlying a fine to coarse gravel. At low rates, the river flows in a sandy channel within the flood plain banks. In high flood, the river brims over a lower flood plain and for extremely high floods, over a second extensive flood plain varying up to one mile in width.

Since the intake has to operate when the flow in the river is low, the intake level must be low and its area must be large to allow water to be drawn from the river at a small depth. The intake must be designed so that the sediment bed load is diverted and debris is prevented from lodging at its entry. Since the intake will be operated at high flows, the pumps must also be protected from extraneous unsteadiness in the river flow.

In the early stage of investigation, three sites for the river pump intake were chosen for preliminary consideration. Two of the three sites (Site 1 and Site 2) were rejected after geologic and economic, as well as hydraulic factors, had been taken into account.

Volume I of this report deals with the basic information regarding the history and prototype data of the Hunter River at Site 3. This information is useful for subsequent model investigation of the pump intake, the details of which are given in Volume II of this report.

The datum of levels used in this report is Standard Datum.

REPORT 110.

HYDRAULIC STUDIES FOR LIDDELL POWER STATION.

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1. Introduction

1.0 General

The Liddell Power Station is a new project under design and construction by the Electricity Commission of New South Wales. The scheme provides for a new thermal power station with four steam turbine alternator units each of 500 megawatts to supply additional power for the New South Wales network. Coal for the power station will be supplied from open cut mining operations from a colliery close to the power station site.

Cooling water for the power station will be circulated in an artificial lake (the cooling water pond) to be created in a portion of the Hunter River on an intermittent water course known as Gardiner's Creek. A rock and earth fill dam some 140 ft. high is under construction to create the artificial lake. The storage capacity of the lake is approximately 120,000 acre-feet at its full supply level.

The site of the power station is between two arms of the lake and cooling water will be drawn from one arm and discharged into the other. The initial filling and the subsequent make-up water for the pond is to be drawn from the Hunter River.

Fig. 1 shows a general view of the Liddell Power Project, which also shows the relative position of the power station, the cooling water pond and the river pumping station, which is at one of three possible sites chosen for detailed investigation.

1.1. Comparison of Pump Intake Sites

In the early stage of investigation, three alternative pump intake sites in the Hunter River were considered (Figs. 2 and 3). Site 1 is about 1 mile downstream of the confluence of the Hunter River and Wollombi Brook. Site 2 is at the confluence of the Hunter River and Bayswater Creek and Site 3 is at the confluence of the Hunter River and Saltwater Creek.

Generally speaking, a pump intake should be located on the outside of a bend, on the steeper bank of the river, where the intake can be installed close to the bank. All of the three sites considered have this advantage.

Site 1 is downstream of the Hunter River and Wollombi Brook, and it would have more water than the other two sites because the Wollombi Brook flow would be included.

On the other hand, Site 1 is most distant from the cooling water pond where the pumped water will be stored. The distances from Site 2 and Site 3 to the cooling water pond are approximately the same. Not very far from Site 3, there is a ridge dividing the basin of Saltwater Creek and the catchment of Gardiner's Creek. The water can be pumped to a high spot within a short distance of the intake and it will then flow to the cooling water pond by gravity.

Therefore, Site 1 and Site 2 were eliminated due to economic reasons and further investigations were concentrated on Site 3. In this report (Volume I), the words "pump intake site" or simply the "site" refers to Site 3, unless otherwise stated.

1.2 Capacity of the Pump Intake

The long-term purpose of the pump intake is to supply make-up water for the cooling water pond. In the power station, the cooling water forms a closed circuit, with the used water returned to the pond. There will be some loss of water from the pond by evaporation, seepage and wastage. The loss due to these causes is estimated at 40 cubic feet per second (c.f.s.)

The riparian flow in the river downstream of the site is 100 c.f.s.* Therefore, if the river has a flow equal to or above 140 c.f.s. throughout the year, the design capacity of the pump intake will be 40 c.f.s. Unfortunately, the flow in the Hunter River is very low for a large part of the year. Water can be pumped for only part of the time in a year and consideration must be given to an intake of higher capacity so that pumping can be operated when the river is in fresh and flood flows.

From the flow records of the Hunter River for a period of 50 years from 1913 to 1962, the Electricity Commission of New South Wales derived a flow duration curve at Jerry's Plains near Site 3. The flow duration curve is shown in Fig. 4. This flow duration curve is, in fact, an average curve over the 50 year period. For a dry year, the river will have a lower flow for a greater percentage of time, hence the flow duration curve for a dry year will be shifted towards the left, whereas for a wet year, the flow duration curve will be shifted towards the right.

In Fig. 4, a pump capacity-duration curve is also drawn. This pump capacity-duration curve is derived from the following relationship

$$Q_p \times T_{pc.} = 4000 \qquad 1.1.$$

where Q_p is the design capacity of the intake in c.f.s. and T_{pc} is the required duration of operation in per cent of time. The product of Q_p and $T_{pc.}$ equal to 4000 is apparent. If the design capacity of the intake is 40 c.f.s. the required duration of operation will be 100 per cent of time. To this design capacity, the riparian flow of 100 c.f.s. is added, over which the operation of the intake can be started.

The two curves in Fig. 4 intersect at 200 c.f.s. This implies that, if the capacity of the intake is designed at 100 c.f.s. the required duration

* This figure has been subsequently changed to 50 c.f.s. However, the 100 c.f.s. riparian flow was used in the investigation because it does not affect the operation of the intake except at low river stages which will be discussed in Volume II of this report.

of pumping is 40 pc. of time, and for an average year, the river would also have the required flow to be pumped.

However, consideration must be given to the flow of the river in drier years, and also from the consideration of the arrangement and size of the pumps, the design capacity of the intake is fixed at 221 c.f.s. with three pumps at 55 c.f.s. each and two at 28 c.f.s. each.

An analysis of the Hunter River flow and the quantity of water available for pumping at the site can be referred to in E.C. Research Note 55, by the Electricity Commission of New South Wales.

1.3 The Pumping Plant

At the beginning of the investigation, three choices regarding the pumping plant were considered in respect to Site 3. These were a seepage trench in the alluvial flats upstream of Saltwater Creek, an underground pumping station with forebay desilting facilities and a bankside low head pumping station with a settling pond followed by high lift pumps.

A model investigation was carried out for the study of the size and efficiency of a settling chamber required by an underground pumping station. It was found that the size of the settling chamber would be enormous and substantial excavation would be involved to accommodate such a chamber. This proposal was therefore discarded.

Following suggestions by Mr. R.A. Hill of Leeds, Hill and Jewett Inc., a consultant to the Electricity Commission of New South Wales, consideration was given to a free standing structure supporting five low head mixed flow pumps. The proposal originally put forward by Hill, is shown in Fig. 5. An intake structure to accommodate the pumps to suit local conditions was evolved as a result of a detailed model study as described in Volume II of this report.

2. Historical Study of the Site

2.0 General

As has been described in Section 1, the pump intake is to be located at Site 3 of the three possible sites chosen for preliminary investigations. Since the intake structure is of the free standing type built in the river, knowledge of possible change of the river course and of the river cross sections at the site, especially after big floods, is important.

In order to study the change in the river, past and recent survey data were used. The available data were compared with each other and the changes of the river were revealed.

As a result of this study, it was found that a stable bank existed on the left side of the river, downstream of the confluence with Saltwater Creek, between Survey Sections 7 and 11 of the site.

2.1 Basic Information

To facilitate the study of the change of the river, aerial photographs of the past as well as recent survey data were used. Two aerial photographs, one taken in 1938 and another in 1956 were used. These two aerial photographs are shown in Figs. 6 and 7. Fig. 7 also shows the bounds of a model built to study the disposition of the intake. These two aerial photographs were later reduced to plans of the same scale for comparison. Two other plans which had been reduced from aerial photographs of 1955 and 1964 were also used. The survey data included two surveys of the site, one in 1964 and another in 1965. The information used in this study is summarised in Table 1.

Table 1: Historical Information

Date	Discharge (c.f.s.)	Information
1938	Unknown	Aerial photo - cannot be reduced to contours.
15th May 1955	800 (Estimate from flow at Singleton less flow at Bulga)	Levels taken by contouring from aerial photo.
17th April 1956	2700 (Flow at Singleton)	Aerial photo - no contour map made.
15th Nov. 1964	175 (Flow at Singleton)	Contour plan from aerial photo
July 1964	400 (Estimate from water level at survey section 7)	Survey
21st June 1965	41 (Gauged)	Survey

With the available information it was found more convenient to study the changes in the river over the entire reach for each interval of time rather than by looking at each area over the entire period. The river courses in 1938 and 1955 were first compared. This comparison showed not only the change of the river over a period of 17 years, but also the change after a record flood of 421,000 c.f.s. in the river in early 1955.

The river courses as shown in the plans from the 1955, 1956 and 1964 aerial photographs were then compared to study the changes in the subsequent years. The course of the river near the pump intake as shown in the 1955 plan which was a more detailed reduction from the aerial photographs than the other, was compared with the survey plan of 1965. The river cross-sections as shown in the 1955 plan were also compared with those from the 1964 survey, which showed more details than the 1965 survey.

2.2 Major Floods in the Hunter River from 1942 to 1964

From 1942 to 1964 there were 23 floods in the Hunter River with peak dischage over 10,000 c.f.s. at Singleton. Of these floods, 17 occurred between 1942 and 1955 and three of them were over 100,000 c.f.s. The flood in February 1955 was a record flood with a peak discharge of 460,000 c.f.s. at Singleton. A 100,000 c.f.s. flood was recorded in June 1964 and there has been no flood of that magnitude since that date. Table 2 shows the peak discharge of floods over 10,000 c.f.s. at Singleton between 1942 and 1964.

Table 2: Floods in Hunter River with peak discharge over 10,000 c.f.s. at Singleton from 1942 to 1964

Flood of	Peak Discharge c.f.s.	Flood of	Peak Discharge c.f.s.
July 1942	24,000	June 1951	82,000
Oct. 1942	42,000	Aug. 1952	94,000
June 1945	30,000	Aug. 1952	107,000
April 1946	42,000	May 1953	44,000
June 1949	150,000	Feb. 1954	40,000
Feb. 1950	73,000	Feb. 1955	460,000
April 1950	48,000	March 1956	42,000
	(59,000	March 1956	24,000
June 1950	(65,000	June 1956	46,000
	(75,000	Feb. 1962	14,000
July 1950	34,000	May 1963	26,000
Nov. 1950	55,000	June 1964	100,000
Jan. 1951	90,000		

2.3 Comparison of the River Course as in 1938 and in 1955

Fig. 6 shows the Hunter River near the pump intake site. The aerial photograph was taken in 1938 but the exact date and hence the flow in the river are not known. The river course was reduced to a plan as shown in Fig. 8.

Fig. 8 also shows the river course reduced to a plan from an aerial photograph taken in 1955 for the purpose of comparison with that in 1938. The aerial photograph of 1955 was taken after the record flood in the Hunter River which occurred in February of that year with a peak discharge estimated at 421,000 c.f.s. at the site (Section 3.11). The aerial photograph was taken on 15th May 1955 and the flow in the river at the time was estimated at 800 c.f.s. Judging from the width of the river, the flow in 1938 when the photograph was taken was much less than this figure of 800 c.f.s.

From Fig. 8, in both 1938 and 1955 the river had a straight reach of about 500 yards between E388,200 and E388,700 and the water flowed east. East of E388,700, the river in 1938 swung around what appeared to be a corner of a low flood plain as shown in Figs. 6 and 8 and flowed north-east. In 1955, the river had a straight reach between E388,700 and E389,040 with the water still flowing east. It appears that the corner of the low flood plain had been eroded away between 1938 and 1955.

Comparison of the river course in 1956 and 1964 as shown in Figs. 9 and 10 indicates that this area did not change again after 1955.

East of E389,040, the river in 1955 was divided into two channels, one flowing close to the left bank of the river which used to be the low flow channel and another one close to the right bank. The two channels re-united again after a distance of about 300 yards, leaving an island between them which was an exposed gravelly bed at low flow. Apparently, the right channel was cut during the big flood in February 1955. It can also be seen that the left bank of the river within this reach has moved south about 50 yards compared with that of 1938. The change of this bank could have been a gradual change over the period or a sudden change as a result of the big flood. The substantial height of the bank in 1955 above where the river flowed in 1938 (Figs. 8 and 13(d)) mitigates against the conclusion that this change was caused entirely by the 1955 flood, a conclusion which might otherwise have been accepted. However, this bank has remained in approximately the same position since 1955. Downstream of the confluence with Saltwater Creek, there were signs of the left bank being badly eroded (as was noted on the plan derived from the aerial photograph of 1955) probably as a result of the flood. Both the water's edge and the high bank on the left of the river in 1955 are shown in Fig. 8. The left bank of the river within this reach was very steep. It rose from the water's edge to the high bank by about 30 ft. within a distance of only about 50 ft. However, Fig. 8 shows that the water's edge in 1938 and in 1955 remained in approximately the same position, showing no great change of the low bank on the left of the river. It follows that a steep bank must also have existed in 1938.

Downstream of the island formed by the two channels in 1955, the river in 1938 flowed south and then south-east, following the higher bank on the right of the river, and leaving a low sandy exposed bed on the left bank of the river. In 1955, the river shifted course and flowed over this exposed bed on the left bank of the river leaving the old 1938 channel dry. This resulted from the straightening of the upstream reach of the river during the flood. The right channel that had formed just opposite to the confluence with Saltwater Creek was filled up very rapidly. This can be seen from the aerial photograph of 1956 as shown in Fig. 7 - such a channel no longer existed after about only one year's time. After the right channel was filled up, the river at low flow flowed along the channel on the left of the river, and downstream of the confluence with Saltwater Creek, it took a course approximately the same as that in 1938.

2.4 Comparison of the River Course as in 1955 and in 1956

Fig. 9 shows the river courses in 1955 and in 1956. In general, the river in 1956 had a greater width than that of 1955, because the flow in 1956 was 2,700 c.f.s. and that in 1955 was 800 c.f.s. at the time when the aerial photographs were taken. It can be seen that upstream of the confluence with Saltwater Creek, the river followed approximately the same course. Opposite the confluence, the channel close to the right bank of the river cut by the 1955 flood was already filled up. The river flowed around a bend, leaving an exposed bed just opposite to the confluence. The water's edge of the left bank downstream of the confluence had no great change within this period. Further downstream, the river took approximately the course of 1938, rather than that of 1955, except that the sand bank on the left of the channel was mostly covered with water in 1956, the flow being much higher than in 1938.

2.5 Comparison of the River Courses as in 1956 and in 1964

The river course from the 1964 aerial photograph is shown for comparison with that from the 1956 photograph in Fig. 10. It can be seen that the river followed approximately the same course, except that in 1964, the width of the river was much smaller because of the low flow in the river (2700 c.f.s. against 175 c.f.s.)

Downstream of the confluence with Saltwater Creek, the river in 1964 flowed around a bend, and was close to the steep left bank. The position of the water's edge on the left of the river was about the same for 1964 as for 1956.

Further downstream, the width of the river in 1964 was smaller than that of 1956, due to a lower flow in the river. The course of the river within this reach followed very closely that of 1938.

2.6. Comparison of the River Courses as in 1938 and in 1965

Fig. 11 shows the river courses in 1938 and in 1965, and indicates the overall change of the river course over that period.

Upstream of the confluence with Saltwater Creek, the river in 1965 had a straight reach flowing east, instead of north-east as in 1938.

The confluence with Saltwater Creek in 1965 was about 50 yards south of that in 1938. This change was first noticed in 1955 as discussed in Section 2.3, and it has remained there since.

Downstream of the confluence, between Survey Sections 7 and 11, the river in both years was flowing within the low flow channel. The width of the river within this reach was greater in 1938 indicating a flow higher than 41 c.f.s.

Downstream of Survey Section 11, the river in both years followed approximately the same course.

2.7 Comparison of the River Course of 1955 with the 1965 Survey

Fig. 12 shows a survey of the Hunter River in 1965 between Survey Sections 3 and 14, which corresponds to the reach of river between E388,800 and E389,600. In the same figure the course of the river in 1955 is also shown. The flow of the river during the 1965 survey was only 41 c.f.s. and that in 1955 was 800 c.f.s. By comparison of the two courses, it can be seen that between Sections 3 and 4 the left bank of the river was cut in by about 50 ft. between 1955 and 1965. Between Survey Section 5 and the confluence, the water's edge in the 1965 survey was inside that of 1955. Actually, this is only a result of the lower water surface level of the low flow in 1965 - the bank of the river between these sections was very flat as can be seen in Figs. 13(c) and 13(d) which show the river cross-sections. Between the confluence and Survey Section 11 there was no noticeable change of the left bank. Downstream of Survey Section 11, the river in 1955 flowed over the exposed bed of the river on the left side of the river. As soon as the right channel between sections 7 and 11 left by the 1955 flood was filled up, the river flowed close to the right bank below section 11 at low flow, leaving the bed on the left of the river again exposed. The low flow channel in 1965 downstream of Section 11 was approximately the same as that of 1938, and also of 1964.

2.8 Comparison of River Cross Sections

Figs. 13 (a) to 13 (k) inclusive show the river cross-sections with data reduced from the 1955 aerial photograph and from the 1964 survey. The positions of the survey sections are given on Fig. 12, the origin of distance being at the survey pegs. The changes in the river cross-section are discussed in the following sub-sections.

Survey Section 3 (Fig. 13(a)). Erosion occurred to a depth of 10 feet over a width of 80 feet of the left bank, which is part of the flood plain upstream of the confluence of the Hunter River with Saltwater Creek. This has probably been caused by floods subsequent to 1955, for example the June 1964 flood of 100,000 c.f.s. Filling-up of the river bed up to about 5 feet is seen on the right hand side of the river.

Survey Section 4 (Fig. 13(b)). There was erosion to a depth of 10 feet over a width of 100 feet of the left bank and filling up of the river bed on the right side of the river as for Survey Section 3.

Survey Section 5 (Fig. 13(c)). There was no great change of the left bank of the river. Filling-up of the river bed on the right side of the river occurred up to about 5 ft. The far, upper bank, on the right side has been lowered by 3 to 5 ft., presumably owing to a combination of erosion in the period 1955 to 1964 and undermining followed by collapse in floods such as that of June 1964.

Survey Section 6 (Fig. 13(d)). No change apparent in the left bank. Part of the island which was left behind after 1955 flood was washed away to form the existing river channel. The far side of the island as well as the channel between the island and the right bank was filled up to about 6 ft. The right bank of the river on the far side is shown to be lowered as at Survey Section 5.

Survey Section 7 (Fig. 13(e)). Although there is evidence from 1955 aerial photograph of this region being badly eroded, the left bank of the river has not changed much since 1955. By comparing the level of the exposed bed on the right hand side of the river in 1964 with that of the island formed after the 1955 flood, it can be seen that the island has been lowered by several feet to the present exposed bed level. The right channel of 1955 was filled up by about 5 ft. to form the existing exposed river bed. As at Survey Sections 5 and 6, the far, upper right bank has been lowered.

Survey Section 8 (Fig. 13(f)). No great change of the left bank of the river is noticed. The exposed bed has been lowered by about 2 ft. to the present bed level.

Survey Section 9 (Fig. 13(g)). Not much change of the left bank of the river. The exposed bed has been lowered by about 2 ft. to the present bed level.

Survey Section 10 (Fig. 13 (h)). The left bank above RL. 230 has been slightly eroded. The bank caved in by about 10 ft. No change of the bank below RL. 230. The exposed bed on the right side of the river has been lowered by about 1 ft.

Survey Section 11 (Fig. 13(i)). Slight erosion of the left bank as at Survey Section 10. This bank has caved in also about 10 ft. The channel on the right hand side of the river cut by the 1955 flood has been filled, and the river bed has been raised several feet in this part to the present level. The far right bank has been cut in.

Survey Section 12 (Fig. 13(j)). No great change of the left bank is noticed. The 1964 channel is deeper on the right hand side of the river than on the left. A heap of sand (island) left after the 1955 flood in the river has been washed away. The left side of the river bed will be exposed at low flows.

Survey Section 13 (Fig. 13(k)). No change of the left bank of the river is noticed. The 1964 river bed is higher in the middle of the river and the channel is deeper on the right hand side of the river than on the left. A heap of sand (island) left after the 1955 flood has been washed away. The river bed on the left side of the river will be exposed at low flows. There is some slight erosion of the right bank of the river.

2.9 Conclusions

As a result of the historical study, the following conclusions have been reached.

2.91: There is no appreciable change of the river from 1938 to 1964 between E388,200 and E388,700, i.e. in the approach reach to the bend. The river has a straight reach flowing east.

2.92: The reach of the river between E388,700 and the confluence with Saltwater Creek has been straightened, and the confluence and the left bank of the river on both sides of it moved south by about 50 yards between 1938 and 1955. The move of the confluence and the bank of the river may have been a gradual change or a sudden change as a result of the big flood in 1955. However, no more change of the position of the confluence and the river banks adjacent to it has been noticed since 1955.

2.93: In the flood of 1955 a channel was cut through the exposed bed just opposite to the confluence with Saltwater Creek, close to the right bank of the river leaving an island between this channel and the normal low-flow channel. As a result of the flow from this new channel, the river cut a channel through a normally exposed bed close to the left bank downstream of Survey Section 11. However, this new channel around the island filled up very rapidly after the flood. With the filling up of this channel, the river downstream of Survey Section 11 resumed its old course close to the right bank of the river, leaving the bed on the left of the river again exposed.

2.94: There is not much change of the left bank of the river between Survey Sections 7 and 11 from 1955 to 1965, the era for which detailed data are available. Though exact upper bank contours cannot be obtained from the 1938 photos, the water line position in this area has remained quite constant and the bank may therefore be taken as relatively stable. Though the high bank between these sections was badly eroded during the 1955 flood, the comparison of the river cross-sections revealed that no great change of the profile of the left bank has taken place since.

2.95: Downstream of Survey Section 11, the existing river course (1965) is approximately the same as that as in 1938.

2.96: A stable bank where the low flow channel has kept its course constant throughout the period of record is found on the left side of the river between Survey Sections 7 and 11, indicating a suitable location for the pump intake at this site.

3. Prototype Information

3.0 General

Prior to the planning of the Liddell Power Station, prototype information regarding the hydraulic features of the pump intake site was meagre. Daily flow and flood peak discharges were derived from nearby gauging stations, namely, Singleton on the Hunter, Bulga on Wollombi Brook Plashett on Slatwater Creek, Kerrabee on the Goulbourn River and Muswellbrook on the Hunter. The location of these gauging stations is shown in Fig. 2.

Since the conception of the construction of a pump intake at the site, two surveys were made. One of the surveys was made in July 1964, when the flow in the river was estimated at 400 c.f.s. Another survey was made on 21st June 1965, when the river flow was gauged at 41 c.f.s. at the site.

Several field investigations were made to the site between 1964 and 1968. The data obtained are to be discussed in the following sections.

3.1 Flood Data

3.11 The 1955 Flood

The largest flood experienced in the Hunter Valley in the last 100 years was the 1955 flood. During that flood, the peak discharge at Singleton was 460,000 c.f.s. The peak recorded at Bulga on Wollombi Brook, a tributary of the Hunter River, was 39,000 c.f.s. Therefore, the peak flow above the confluence of the Hunter River and the Wollombi Brook was estimated as 421,000 c.f.s. (460,000 c.f.s. - 39,000 c.f.s.)

For the 1955 flood, the flood levels near the pump intake site were obtained from information by local residents. The levels were

(1) At Plashett cowshed, the flood reached a level of 273.7 ft. reduced to the power station datum (P.S. datum)

(2) At Coles, the flood level given with reference to a cross bar on a telegraph pole was at RL. 272.0.

(3) At Gee's place, it was at RL. 268.6 as given by stone markers or at RL. 264.8 as given by debris left by the flood and by the height of a fork in a tree from an eye witness account.

The location of these places with respect to the intake site is given in Fig. 3.

The distance between Plashett and Coles where the levels were taken is about 4,000 ft. and it is about 4,500 ft. between Coles and Gee's place. For the second reach, if the flood level at Gee's place was taken as 268.6 ft., the water surface slope during the flood would be 0.0008. On the other hand, if the flood level of 264.8 was used, the water surface slope would be 0.0016. The water surface slope during that flood for the first reach was 0.0004, giving an average slope over the whole reach of 0.0006 or 0.0010 depending on the figure used for the second reach.

A backwater analysis of the river surface profile carried out by the Electricity Commission of New South Wales (Section 4.2) indicates that, for a discharge of 400,000 c.f.s., the river surface passes the level at Plashett as indicated. The computed level at Coles is at RL. 273.0, being 1 ft. higher than the indicated value of RL. 272.0. The computed level at Gee's place is at RL. 268.6, the higher figure given by local residents.

3.12 The 1964 Flood

For the flood of June 1964, the peak discharge at Singleton was 97,000 c.f.s. and that at Bulga on Wollombi Brook was 29,000 c.f.s. The peak discharge upstream of the confluence of the Hunter River with Wollombi Brook was estimated as approximately 68,000 c.f.s. During the peak, the flood level at Plashett was 250.8 ft., reduced to the power station datum. The water surface slope measured during the recession period of the flood was 0.00069. This measurement was taken downstream of the confluence of the Hunter River and Saltwater Creek.

3.13 Flow from Saltwater Creek

As has been state in Section 2, a suitable location for the pumping station at the site is on the left bank of the Hunter River just downstream of the confluence with Saltwater Creek. To investigate the hydraulic features of this site, the effect of flow from Saltwater Creek has to be included.

Table 3 shows the peak magnitude of some floods as well as some daily flows during a period from March 1956 to December 1960. The flows in Saltwater Creek were taken at Plashett, those in the Hunter River were taken at Singleton and the Wollombi flows were taken at Bulga. The flows in Saltwater Creek were plotted against those in the Hunter River after subtracting the reading for the Wollombi at Bulga from that for the Hunter at Singleton and this plot is shown in Fig. 14. A logarithmic plot is shown for ease of observation and the regression curve was derived arithmetically. The points in Fig. 14 show a degree of scatter. However, a regression curve of Q_s and Q_H can be drawn with

$$Q_S = 0.066\ Q_H$$

where Q_S = peak discharge in Saltwater Creek

Q_H = peak discharge in Hunter River

Moreover, if a line is drawn with $Q_S = 0.25\ Q_H$, the majority of the points, especially those for higher discharges lie on the right and below this line. (See Fig. 14)

Thus the conditions applying at the confluence, range from the condition of no flow from Saltwater Creek to a maximum flow from Saltwater Creek, of one-quarter of the flow in the Hunter River downstream of the confluence.

Table 3: Peak Magnitude of floods in the Hunter River and its tributaries.

Date	Hunter River c.f.s.	Wollombi Brook c.f.s.	Saltwater Creek c.f.s.
2.3.56	19,433	13,000	1,610
9.3.56	40,267	1,567	2,265
16.3.56	17,300	6,666	750
2.4.56	5,325	400	206
1.5.56	9,900	69	725
25.6.56	29,600	9,530	655
20.2.57	15,800	900	16
15.4.58	26	11	16
30.6.58	167	20	32
16.8.58	103	5	86
10.10.58	750	5	32
16.12.58	320	5	34
27.1.59	370	0	20
7.2.59	480	8	719
18.2.59	6,365	700	245
4.3.59	3,700	103	815
17.4.59	450	32	50
22.1.60	327	300	74

3.2 Low Flow Data

3.20 General.

Low flow data of the river at the pump intake site were collected during several field investigations. The data collected included discharges in the river, river surface levels, velocities and flow pattern.

3.21 River Surface Levels.

During each of the field investigations, the river flow was gauged and the river surface level was measured at intervals of about 200 ft. along the reach of interest. Table 4 shows the river discharge and the river surface level at Survey Section 11.

Table 4: River Discharge and Water Surface Level at Survey Section 11.

Date	Discharge c.f.s.	Water Surface Level at Section 11 ft.	Gauging Location
21.6.65	41	224.69	Sections 9 and 6
19.10.65	250	225.50	Low Level Bridge*
6.12.65	220	225.60	Low Level Bridge
	195 (average)		Sections 11 and 9
16.12.65	1560	227.78	Low Level Bridge
17.12.65	1600	228.19	Low Level Bridge

* The low level bridge is about 3 miles upstream of the site.

The water surface profile obtained is shown in Fig. 15.

3.22 Water Surface Slopes.

Fig. 15 shows that at low flows, there is a sharp drop of the water surface between Survey Sections 6A and 5A. It was also observed that there were some rapids between these sections. The sharp drop of the water surface and the rapids are caused by rocky bed just upstream of the confluence with Saltwater Creek. Upstream of these sections and downstream of the confluence, the water surface slopes are mild. At higher flows, for example, the 1560 c.f.s. and 1600 c.f.s. flows, when the rapids are drowned out, the water surface slope becomes more uniform over the entire reach from survey Sections 1 to 13. The water surface slope for these flows is summarised in Table 5.

Table 5: Water Surface Slope at Low Flow

Date of Measurement	21.6.67	19.10.65	6.12.65.	16.12.65	17.12.65
Discharge c.f.s.	41	250	220	1560	1600
Average water surface slope between Section 1 and 13	0.00188	-	-	0.00092	0.00094
Average water surface slope Sections 7 and 11	0.00024	0.00075	0.00074	0.00126	0.00125
Average water surface slope between Sections 11 and 13	0.00060	-	0.00057	0.00110	0.00127
Average water surface slope upstream of confluence	0.00077	-	-	0.00070	0.00063

From Table 5 or from Fig. 15, it can be seen that the average water surface slope over the entire reach from Survey Section 1 to Survey Section 13 was much steeper at low flows, being 0.00188 for 41 c.f.s. against 0.00094 for 1600 c.f.s. The steeper slope for the low flow was due to the sudden fall of the water surface after the rapids. If this sudden fall of the water surface is excluded in the computation, it can be seen that the water surface slope, downstream of the confluence, increases with the discharge in the river, whereas the water surface slope upstream of the confluence, decreases with the discharge in the river.

3.23 Velocities

Velocity measurements were made at the site during the field investigations. Some of the measurements were made by timing floating objects thrown into the river, passing two observation posts set 100 feet apart between Survey Sections 10 and 11. The velocities thus obtained are summarised in Table 6.

Table 6: Surface Velocity between Survey Sections 10 and 11

Location	Q = 250 cfs	Q = 1560 cfs	Q = 1600 cfs
	Velocity ft/sec.	Velocity ft/sec.	Velocity ft/sec.
Left bank	1.6	4.8	3.7
1/4 width from left bank	1.9	4.9	4.3
Middle of River	1.8	4.9	5.0
1/4 width from right bank	1.7	4.1	4.9
Right bank	1.5	4.0	3.7
Average	1.7	4.5	4.3

Besides between Survey Sections 10 and 11, surface velocities were also obtained at other survey sections. Table 7 shows the surface velocity of the river between Survey Sections 9 and 10 and also between Survey Sections 5 and 6 at Q = 1600 c.f.s.

Table 7: Surface Velocity for Q = 1600 c.f.s.

Location	Between Section 9 and 10	Between Sections 5 and 6
	Velocity ft/sec	Velocity ft/sec
Left bank		5.2
1/4 width from left bank	6.1	4.4
3/8 width from left bank	7.5	
Middle of river	9.5	4.6
1/4 width from right bank		4.2
Right bank	6.1	1.8
Average	7.3	4.1

In some cases, velocity of the river was measured with a current meter. Table 8 shows such velocities at Q = 128 c.f.s. and also at Q = 220 c.f.s. The velocities shown are average velocities over the depth of the river.

Table 8 : Velocity measured with Current Meter

Q = 128 cfs	Survey Section 10	Dist. from left bank (ft.)	6	16	26	36	46	56	66	71				Average
		Velocity ft/sec	0.75	1.6	0.9	1.4	1.5	1.3	1.2	1.0				1.2
Q = 220 cfs	Survey Section 9	Dist. from left bank (ft.)	8	18	28	38	48	58	68					
		Velocity ft/sec	1.6	1.4	1.1	1.7	2.0	1.9	1.6					1.6
	Survey Section 11	Dist. from left bank (ft.)	8	18	28	38	48	58	68	78	88	98	108	
		Velocity ft/sec	1.3	1.3	1.4	1.3	1.5	1.6	1.3	1.3	1.6	1.5	1.6	1.4

Fig. 16 shows the direction as well as the magnitude of the flow at Survey Section 9 and Survey Section 11 at Q = 220 c.f.s.

3.24 Flow Pattern

Near the pump intake site, rapids and reverse eddies were observed near the confluence at low flows. The rapids and reverse eddies are caused by the boundary conditions at the locality.

Fig. 17 is a sketch of the flow pattern at a discharge of 220 c.f.s.

Upstream of the confluence at Survey Section 6 the river bed is formed of hard rocks. This hard, rocky bed starts from the left bank extending towards the middle of the river and from there it bends slightly downstream. At low discharges, the flow over this hard rocky bed is supercritical, and consists of rapids. At the water edge on the right bank, since the hard rocky river bed bends slightly downstream, a pocket of still water is formed, and the water after leaving the rocky edge flows towards the middle of the river. On the left bank of the river after the rapids, there is a group of willow trees. The roots, trunks and some branches of these trees are projecting out from the left bank and this also causes the water near the left bank, after leaving the rocky edges, to flow towards the middle of the river. Therefore, the main stream after the rapids is approximately in the middle of the river, and the velocity is quite high. On both banks, some reverse flows, and even regions of dead water, are created.

Downstream of the confluence, between Survey Sections 8 and 9, there is a big willow tree which is in fact in the river away from the left bank. On the opposite side there is a log, the remains of a big dead tree. The river contracts again at this section, leaving some reverse currents downstream. At a flow of 220 c.f.s. the reverse currents caused by this big willow tree and the log are confined within a short distance downstream of Survey Section 9.

As the rapids and the reverse flows are results of these local boundary conditions, they will be drowned out at high flows when the depth of the river becomes greater and these boundary conditions are no longer dominant. An observation of the river at 1560 c.f.s. showed this was the case. At higher discharges, e.g. the 1560 c.f.s. the direction of the flow was approximately parallel to the left bank of the river.

3.3 River Bed Levels

The river bed is composed of sand and gravel. It can be expected that bed changes will occur as a result of scour during a flood. Accretion will take place when low flow prevails for a considerable time in the river.

A survey of the river bed in July, 1964, showed the river bed levels were relatively low. This could have been caused by scour during the 70,000 c.f.s. flood which occurred in June 1964. From July 1964 to

July 1965 the river flow did not exceed 500 c.f.s. and a considerable accretion occurred during this period. A survey in June 1965 when the flow in the river was 41 c.f.s. showed that the river bed levels had risen between 6 inches and 2 feet since 1964. Another survey in January 1966 after a series of rises in the river the largest of which had a peak discharge of 1600 c.f.s. on 17th December 1965, again showed considerable changes of the bed shape.

It can be seen that the pattern of erosion and accretion of the river bed is controlled by the topography of the river at the bend. During a flood, scour occurs along the concave bank on the left of the river. The scour holes are then filled up by sediment transport during periods of low flow.

Fig. 18 shows the changes of the river bed level at Survey Sections 9 and 11.

3.4 Flood Deposits

Following the June 1964 flood, a sample of sand and silt was collected from a deposit 18 inches thick, located in a sheltered position approximately 20 feet above the bed of the river and about 2000 feet upstream of Site 2.

It was found that most of the material was between 0.1 to 1.0 mm which indicates that, at that location, sand up to 1 mm size was being carried in suspension during that flood.

The size grading curve of the sample is shown in Fig. 19.

3.5 River Bed Samples

3.50 General

Some samples were taken from the river bed at the pump intake site after the June 1964 flood had receded. The samples were taken at a cross section across the sand bank between the high ground on the right bank and the river. The location where the samples were taken is shown in Fig. 20.

The sand bank at the pump intake site has a fairly level grade from the edge of the water up to the right bank. Along this section the bed material comes in alternate layers of sand and gravelly deposits. A vertical section down through the sand bank exhibits the same sort of distribution. It would appear as though these bands of pebbles were laid down in succeeding floods, and, as the flood receded, so the sand was deposited on top the next flood bringing another load of gravel and so on. Fig. 20 shows the sampling locations A to I as well as a series of bands of stones which were not sampled. The size grading of the samples in shown in Fig. 21.

3.51 Sample A

Sample A was taken from the furthest point on the right bank and represents a deposit from the suspended load. As can be seen, the sand is significantly finer than that in Sample F, which is being moved as bed load at low flows.

3.52 Samples B, C and D

These three samples were taken from the surface of the sand bank, representing the predominant type of material which can be seen. At sand sizes less than 1 mm, the proportion of sand of any given size in each of these samples is the same. If material of all sizes greater than 1 mm is removed from these samples, the resulting distributions of sand in these samples are similar to those for the other sand samples.

3.53 Sample E

This sample was taken in an area of 2 feet square and represents the top layer entirely of a band of large stones near the water's edge. It is not to be assumed that this sample is in any way representative of the bed material, but it does give some indication of the sizes of the larger stones which are present near this section, which at low flows is a rapid.

3.54 Sample F

This sample was taken in the river itself, under the flowing water, and shows the sizes of sand which were being moved as bed load at the time, the flow being about 400 c.f.s. The sand is coarser than that from other locations, particularly that found in Sample A.

3.55 Sample G

This sample was taken from the side of the river in an area where the velocity was very small, and as can be seen, the grading is somewhat finer than that of material being moved as bed load. This is to be expected as the finer particles would be deposited in an area such as this.

3.56 Samples H and I

Sample I was taken on the top of the sand bank at the edge of the river. Sample H was taken from a band of stones underlying Sample I, at a depth of 8 inches to 18 inches. It can be seen that the sand portion of these samples lies in a narrow band, and the addition of stones in Sample H classes this material with Samples B, C and D.

3.6 Suspended Sediment Samples

3.60 General

In order to obtain reliable information of the suspended sediment carried in the river, a "straight through" type of sampler was used for the collection of suspended sediment samples. A "traveller" was set up near Survey Section 9 at the site, which brings the sampler in position when sampling. Fig. 22 shows the set up for suspended sediment sampling at the site.

Since the traveller was installed, suspended sediment samples were obtained for river flows up to 24,500 c.f.s. The samples were analysed for their concentration, expressed in parts per million (ppm) by weight and grain size distributions was an-lysed also for some of the samples.

3.61 Sediment Concentration

Table 9 is a summary of the results from samples taken at the site. It can be seen from the table that, there is a general trend of the sediment concentration to increase from the water surface to the river bed and also from the bank towards the middle of the river. It was also noticed that the sediment concentration increases with the flow in the river.

The sediment concentration, plotted against the river flow is shown in Fig. 23.

In Fig. 23, an assumed sediment rating curve, together with sediment concentrations from other locations of the Hunter River, is also shown. The derivation of the rating curve and the factors that affect the sediment concentration at the site will be discussed in Section 3.7.

Table 9

Suspended Sediment Sampling Results

Date	Position of Sampling		Discharge c.f.s.	Sediment Concent-ration ppm	Remarks
	Dist. from bank	Depth ft.			
13.12.67	73	0	230	336	
13.12.67	73	3	230	970	Some sand present
16.12.67	117	0	1130	1748	Some sand present
16.12.67	117	2	1130	1844	Some sand present
16.12.67	117	4	1130	2474	Some sand present
16.12.67	105	0	1130	1802	Some sand present
16.12.67	105	2	1130	1805	Some sand present

Date	Position of Sampling		Discharge c.f.s.	Sediment Concentration ppm	Remarks
	Dist. from bank	Depth ft.			
16.12.67	105	4	1130	2016	Some sand present
16.12.67	105	6	1130	1933	Some sand present
16.12.67	90	0	1130	1688	
16.12.67	90	2	1130	1567	
16.12.67	90	4	1130	1666	
16.12.67	90	6	1130	1701	Some sand present
16.12.67	63	0	1130	1628	
17.12.65	117	0	1260	974	
17.12.65	117	2	1260	1027	Some sand present
17.12.65	117	4	1260	1131	
17.12.65	117	5	1260	1020	
17.12.65	105	0	1300	1021	
17.12.65	105	2	1300	1045	Some sand present
17.12.65	105	4	1260	1154	
17.12.65	90	0	1300	907	
17.12.65	90	2	1300	968	Some sand present
17.12.65	90	4	1300	964	
17.12.65	90	6	1300	983	
17.12.65	63	0	1300	1058	
17.12.65	117	0	1180	1038	
17.12.65	117	2	1220	1171	Some sand present
17.12.65	117	4	1220	1476	Some sand present
17.12.65	105	2	1180	1334	Some sand present
17.12.65	105	4	1180	1477	Some sand present
17.12.65	105	6	1180	1166	Some sand present
29.6.67	106	3.5	3930	1560	Grain size analysed
29.6.67	106	6	3930	1650	Grain size analysed
29.6.67	106	8.5	3930	1410	Grain size analysed
29.6.67	96	5	3930	780	Grain size analysed
29.6.67	96	8.5	3930	1050	Grain size analysed
7.9.67	73	Surface	8000	1150	Fine clay particles
7.9.67	73	Surface	8000	1150	Fine clay particles
7.9.67	73	Bed	8000	3870	Fine clay particles
7.9.67	73	Bed	8000	2430	Fine clay particles
7.9.67	73	Bed	8000	2550	Fine clay particles
13.1.68	58	1.5	24.500	3500	Grain size analysed
13.1.68	58	5.5	24.500	4600	Grain size analysed
13.1.68	58	9	24.500	2910	Grain size analysed

3.62 Sediment Grain Size

Sediment grain size was analysed for some of the samples taken at the site and the results are shown in Fig. 24.

In Fig. 24, an assumed size grading curve is also shown. The derivation of this assumed size grading curve and the comparison with available data will be discussed in Section 3.8.

3.7 Sediment Rating Curve

A sediment rating curve can be drawn if there are sufficient data relating the sediment concentration to the river flow. Since the installation of the traveller at the site, the river flow did not exceed a few thousand cubic feet per second until recently, and information regarding the sediment concentration was therefore lacking. In the absence of reliable data, estimates had to be made during the early stage of investigation.

For design purposes, a sediment rating curve was assumed. This assumed sediment rating curve was derived with a measured sediment concentration of 2000 ppm (parts per million by weight) at a flow of 1600 c.f.s., and an assumed maximum concentration of 50,000 ppm at an extremely high flood. The assumed rating curve is shown in Fig. 23, together with field data obtained since the derivation of this rating curve and also with data at other locations in the Hunter River obtained by the Hunter Valley Research Foundation.

From Fig. 23, it can be seen that for a flow of about 1200 c.f.s, the assumed concentration of 1300 ppm represents approximately the mean concentration of 30 samples, the maximum concentration being 2500 ppm and the minimum 900 ppm.

Two samples at a lower flow of 230 c.f.s. had higher concentrations than the assumed value. The assumed concentration at this flow was less than 100 ppm while the higher concentration of these two samples was 970 ppm.

Samples obtained at higher flows, namely 3930, 8000 and 24,500 c.f.s. showed that their concentrations were lower than their corresponding assumed values.

The samples at 3930 c.f.s. were taken while the pump intake structure was under construction. A small earth dam was built and a diversion channel was dug in the exposed bed on the right of the river at the site to divert the flow from the low flow channel. At 3930 c.f.s. the earth dam was breached, but part of the river was still flowing through the diversion channel which should under natural conditions be confined within the low flow channel at this flow. The suspended sediment would therefore be affected by the fact that part of the flow was diverted through the diversion channel.

At 8000 c.f.s. the flow in the river should also be confined within the low flow channel under natural conditions. The suspended sediment was also thought to be affected by the existence of the diversion channel as for the 3930 c.f.s. flow.

At a high flow of 24,500 c.f.s, the disturbance of the natural conditions by a small earth dam should not affect the river to a great extent. However, a reverse flow developed downstream of the confluence with Saltwater Creek and the sediment samples were taken within this region with a velocity of only about 1 ft/sec. flowing upstream. It is doubted whether the sediment obtained there could represent that in the river outside the reverse flow region.

The Hunter Valley Research Foundation has taken from time to time suspended sediment samples of the Hunter River at various locations. One set of their data was from samples at Singleton about 30 miles downstream of the pump intake site. Most of the data from this set were for flows less than 300 c.f.s. However, for flows over 300 c.f.s. the data followed the same trend as the assumed rating curve with slightly lower concentration for most of the points. It should be noted that the suspended sediment at Singleton would be affected by the flow from Wollombi Brook which is also downstream of the pump intake site.

Another set of data from the Hunter Valley Research Foundation was from samples taken at Muswellbrook, about 30 miles upstream of the site, during the January 1968 flood, the peak at the site being 24,500 c.f.s. The samples were taken at the recession and the sediment concentration was found to decrease with the magnitude of the flow. The data at Muswellbrook lay below the assumed rating curve at the site. However, the flow from the Goulburn River should be taken into account. It was noticed that the Goulburn River carried much greater quantities of sand than the Uper Hunter River. During the January 1968 flood, the peak discharge at Muswellbrook was 23000 c.f.s. at 4.30 p.m. on 12.1.68 and the flow from the Goulburn River at Sandy Hollow was 2300 c.f.s. at 3 p.m. on 13.1.68.

Therefore, as a conclusion, with the data up to date, the assumed sediment rating curve is a reasonable estimate of the suspended sediment at the pump intake site.

3.8 Sediment Grain Size Distribution

Sediment grain size was analysed for some of the samples taken at the site and the results are shown in Fig. 24.

In the samples of the 3930 c.f.s. flow, the suspended sediment was composed of very fine particles. The largest diameter of the particles was less than 0.1 mm and about 85 pc by weight were finer than 0.01 mm.

Much coarser particles were found in the samples of the 24,500 c.f.s. flow. Sand grains up to 0.5 mm diameter were found in one of the samples (the sample taken at mid depth of the river)

An assumed size grading curve is also drawn in Fig. 24. This assumed size grading curve was based on sample of sand and silt collected after the June 1964 flood of 70,000 c.f.s. from a deposit 18 inches thick in a sheltered position approximately 20 feet above the bed of the river and 200 feet upstream of pump intake site No. 2. The size grading curve of the deposit is shown in Fig. 19. A finer portion on sediment was added to the deposit to form the assumed curve since the fine particles would not deposit at the early recession stage of the flood.

In Fig. 24, it can be seen that the size distribution of the sample at mid-depth of the river at 24,500 c.f.s. was close to the assumed distribution. It is likely that even coarser materials may exist in suspension at higher flows.

However, as has been stated in Section 3.7, it is doubtful whether the sediment samples obtained at 24,500 c.f.s. can represent the sediment in the river outside the reverse flow region. The assumed curve is thought to be a fair estimate of the sediment size distribution in the river at the site.

4. Stage-Discharge Relationship

4.0 General

For investigations with river models, it is important to have the stage-discharge relationship. For rivers without such records, this relationship has to be obtained synthetically.

In this investigation, two methods were used to establish the stage-discharge relationship. One of the methods used was the slope-area method. The other was backwater analysis using an FAB1 programme with the aid of a computer.

4.1 Slope Area Method

In the application of the slope-area method, three basic factors should be known. The first one is the geometry of the river cross sections of a longitudinal reach of known length, the second is the character of the river bed so that a suitable roughness factor may be chosen and the third, the slope of the flow surface.

A survey of the site was made in July, 1964, after a flood of 70,000 c.f.s. At the time of the survey, the river flow was about 400 c.f.s. The survey plan is shown in Fig. 25. Another survey of the site was made on 21.6.65, when river flow was 41 c.f.s. The survey plan is shown in Fig. 26. By comparison of the river cross sections of these two surveys (Fig. 18), it can be seen that considerable accretion had occurred during that period. In the derivation of the stage-discharge relationship, the July 1964 data were used. This was because the July 1964 survey were the only data available at that time, and for higher flows, the river bed would conform more closely to that of July 1964, rather than to that of June 1965. Survey Section 11 and Survey Section 8 were chosen in the computation.

The river bed in the low flow channel consists of medium to fine sand The Manning's roughness coefficient "n" for this sort of material may be estimated as from 0.025 to 0.030. A measurement of the flood stage and water surface slope of the May 1962 flood of 75,000 c.f.s. at Site 1 gave a Manning's roughness coefficient of n = 0.024. However, since the river would flow over the flood plain during a flood at Site 3, a higher figure of n = 0.028 was used in the computation.

An average water surface slope of 0.0006 (or 0.0010, see Section 3.11) was obtained at the site during the February 1955 flood. It was observed that the water surface slope changed with the discharge in the river. A slope of 0.001 was also observed at the site during the recession of the June 1964 flood. However, in the computation, two water surface slopes, i.e. o.0004 and 0.004 were used. The true stage discharge curve would lie between these two curves since the water surface slope for any flow would be between 0.0004 and 0.004.

The stage-discharge curves, for water surface slope of 0.0004 and o.004 respectively, for survey section 11 are shown in Fig. 27.

4.2 Backwater Analysis

A backwater analysis was carried out by the Electricity Commission of New South Wales, using an FAB1 programme with the aid of a computer.

In the computation, survey data were used for low flows and contour maps were used for the overbank areas at high flows.

In the backwater analysis, a Manning's roughness coefficient "n" had to be assumed. Four n-values, namely 0.01, 0.02, 0.03 and 0.04 were used for the low flow channel. It was found that an "n" value of 0.02 gave a backwater curve which agreed with the measured water surface profile at 41 c.f.s. Again, if an "n" value of 0.02 was used for the low flow channel and an "n" value of 0.04 was used for the overbank areas, the computed water surface profile agreed with most of the prototype data of the 70,000 c.f.s. and 40,000 c.f.s. flows.

Figs. 28 and 29 show the computed water surface profile together with the prototype data. A stage-discharge curve for survey section 11 is shown in Fig. 30.

In view of the lack of more reliable information, the stage-discharge curves derived from both methods were used in the model investigation.

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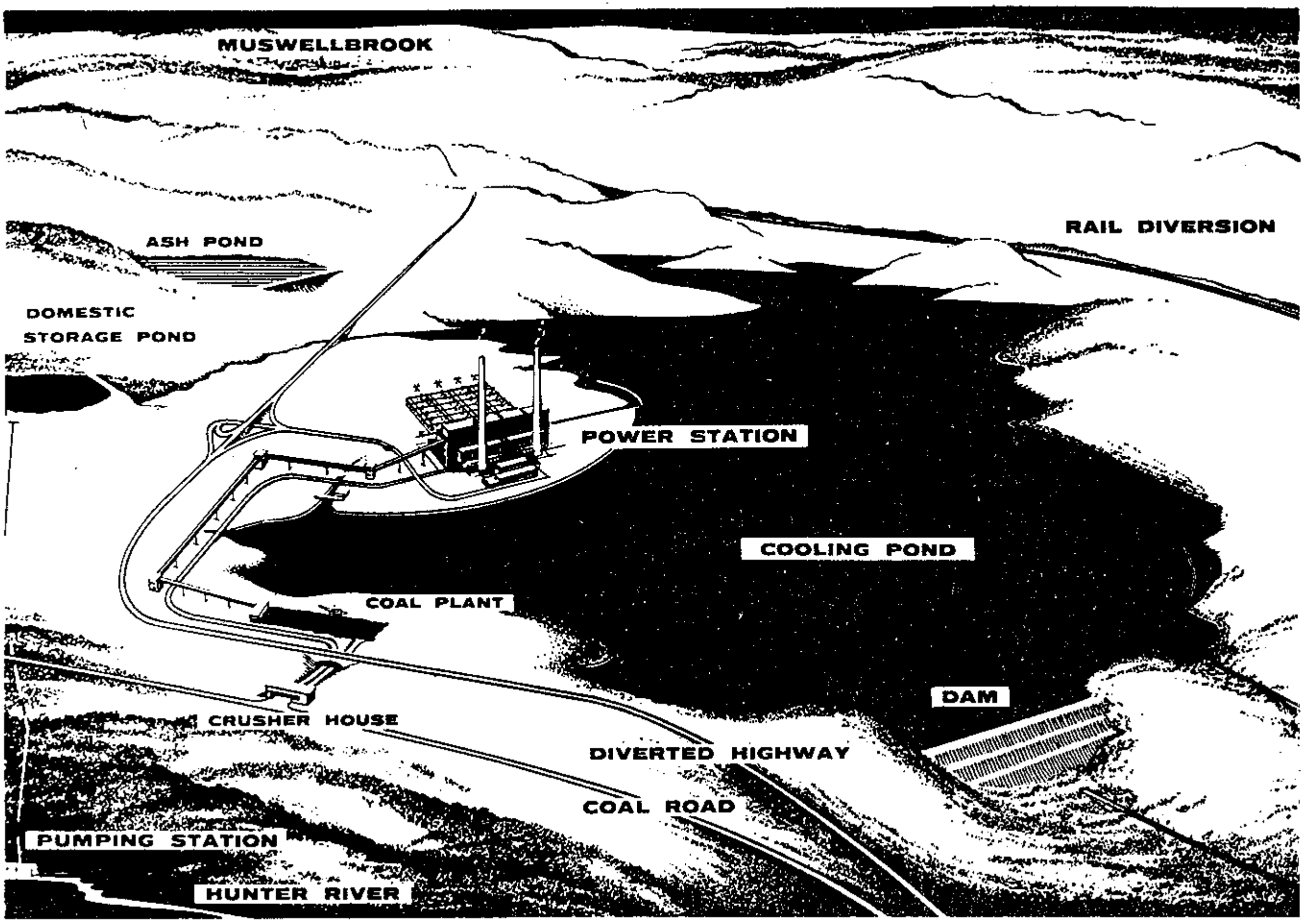

Figure 1: General view of the Liddell Power Project.

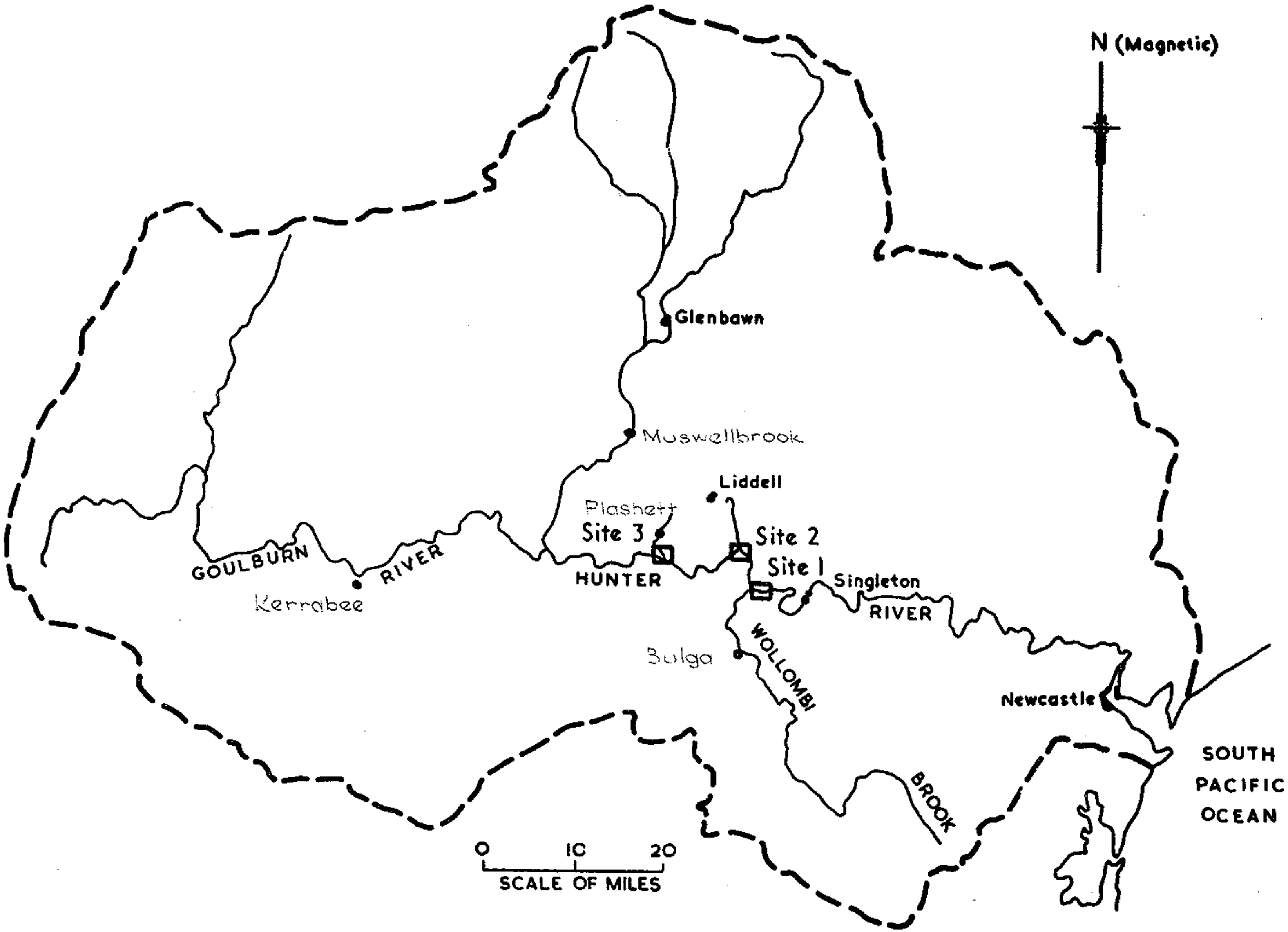

Figure 2: The Hunter Valley (with the proposed pump intake sites)

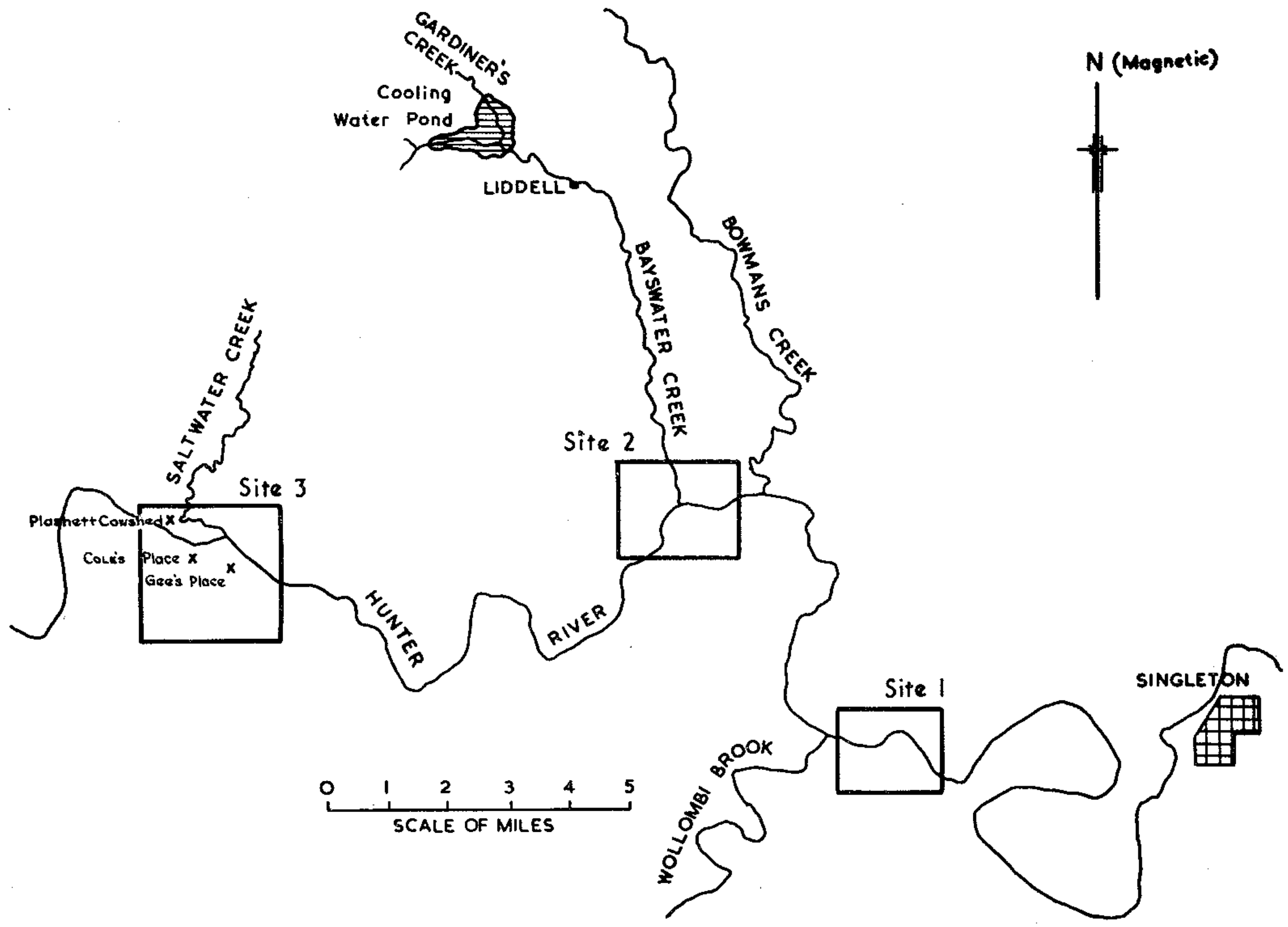

Figure 3: Location of proposed sites for pump intake.

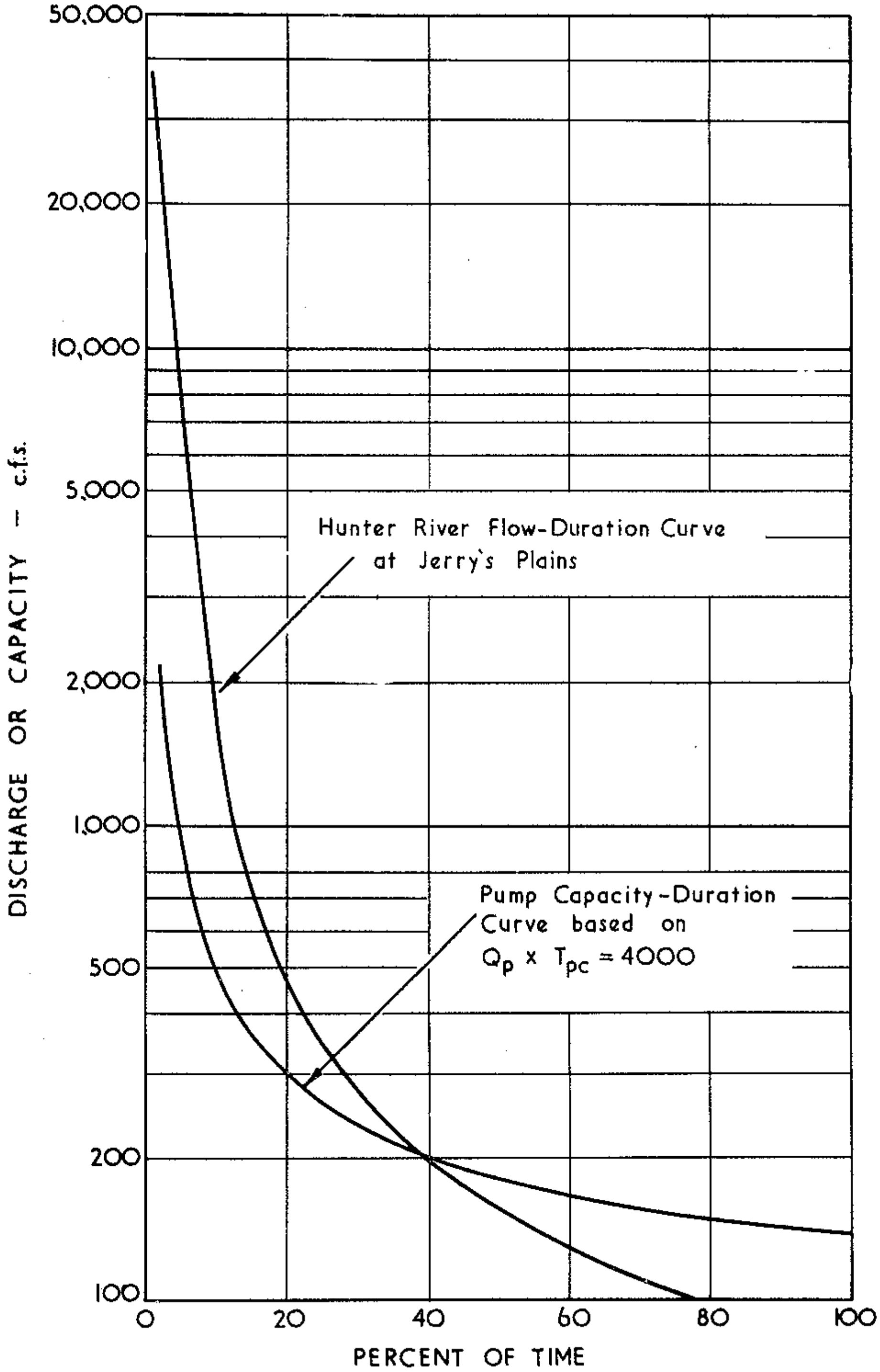

Figure 4: Flow-duration curve and pump capacity-duration curve.

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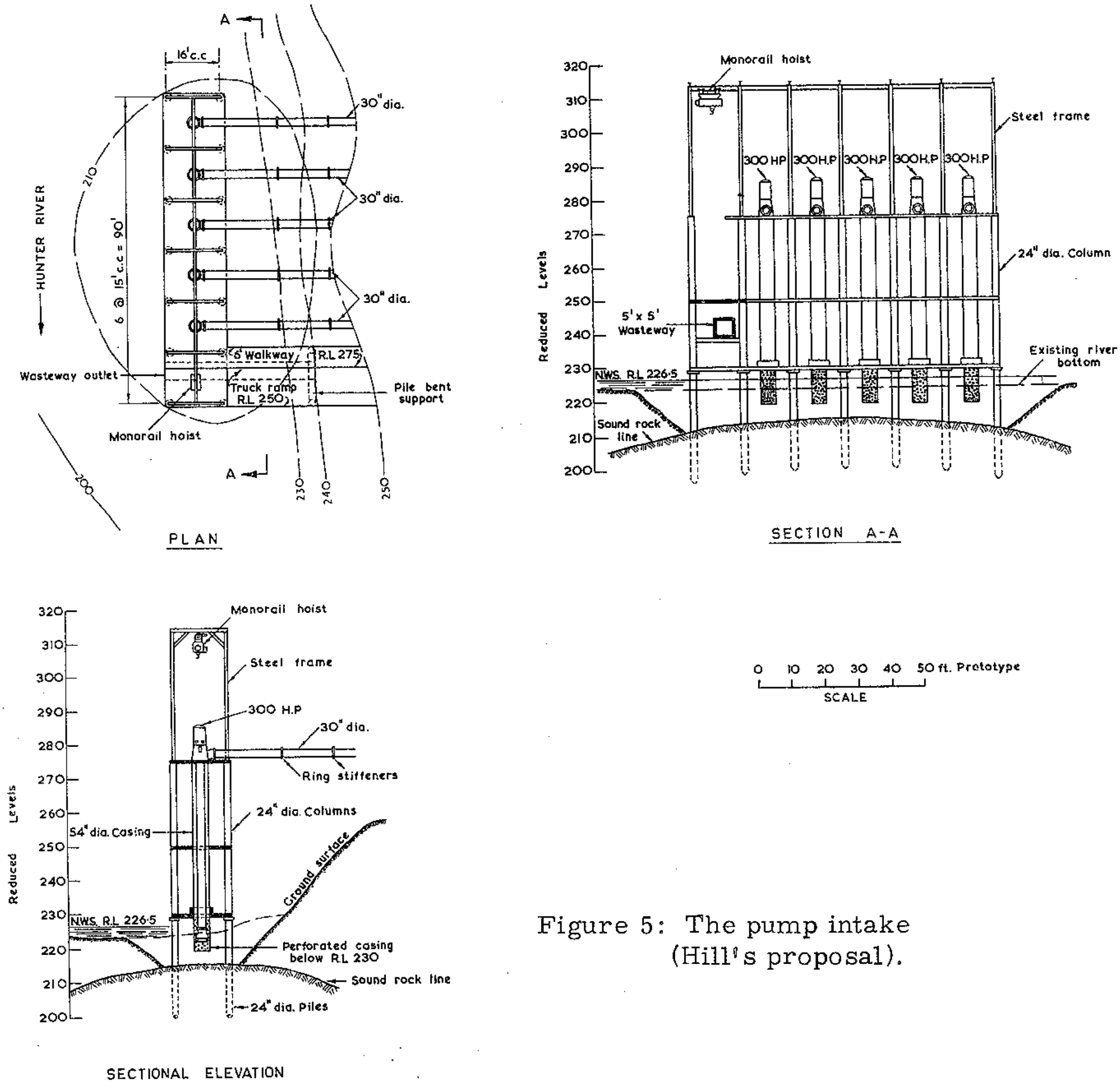


Figure 5: The pump intake (Hill's proposal).

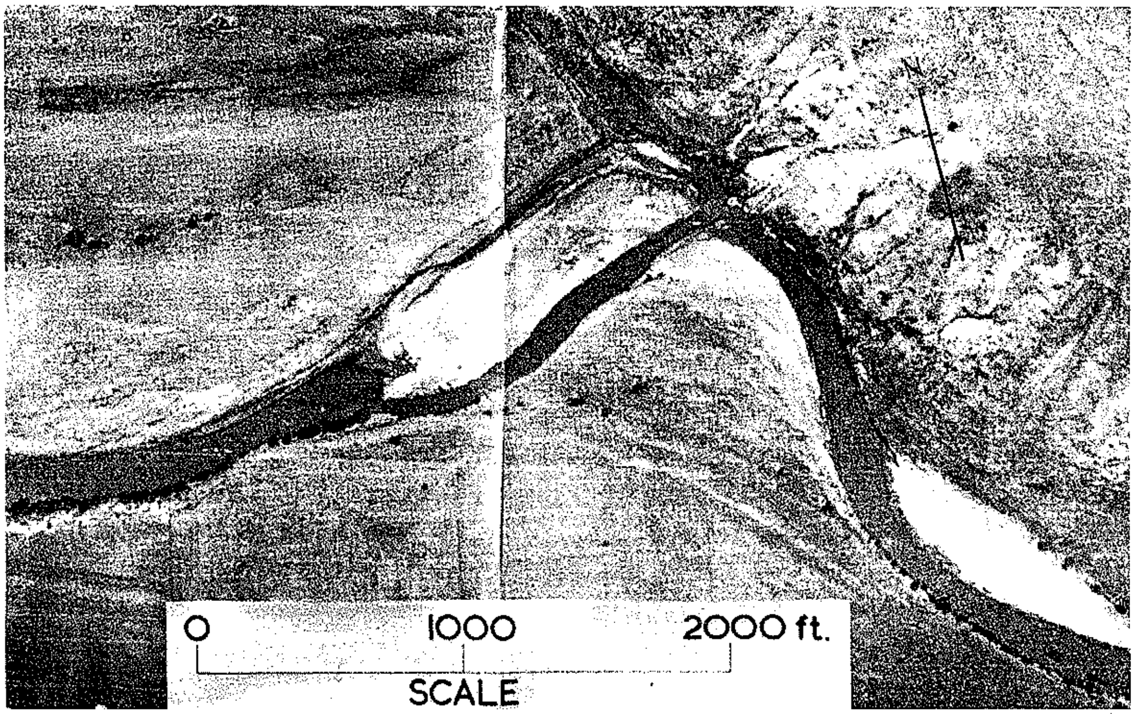


Figure 6: Aerial photograph of Hunter River, 1938.

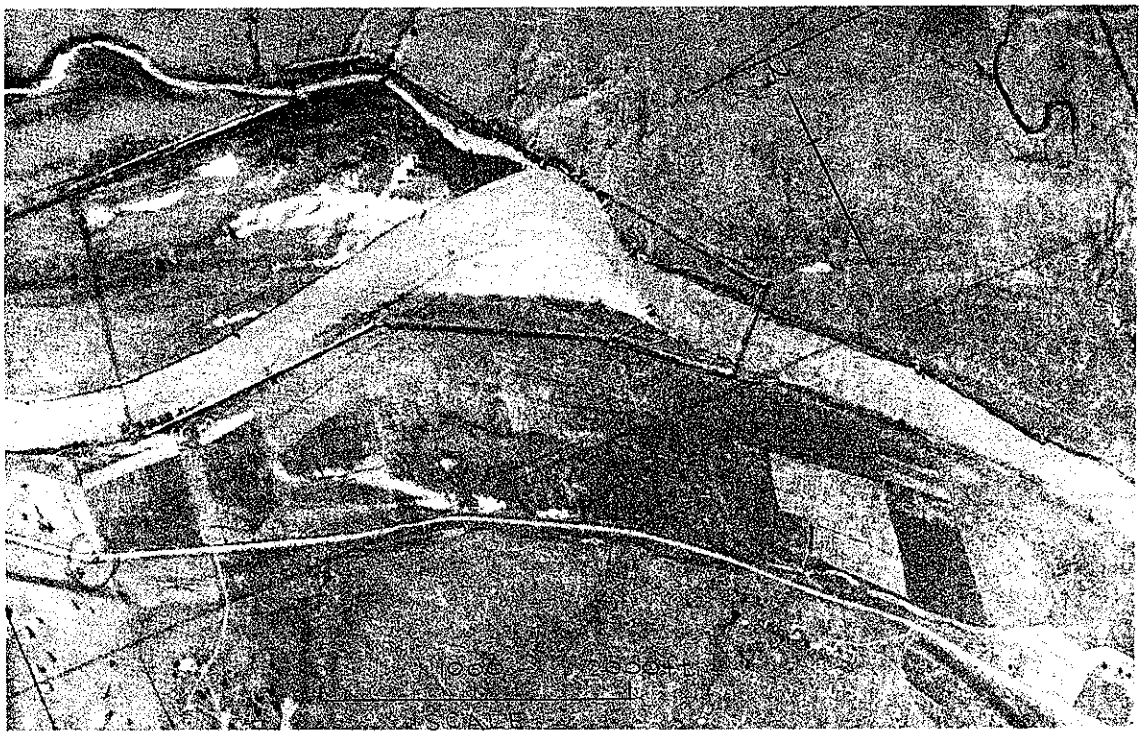


Figure 7: Aerial photograph of Hunter River, 1956.

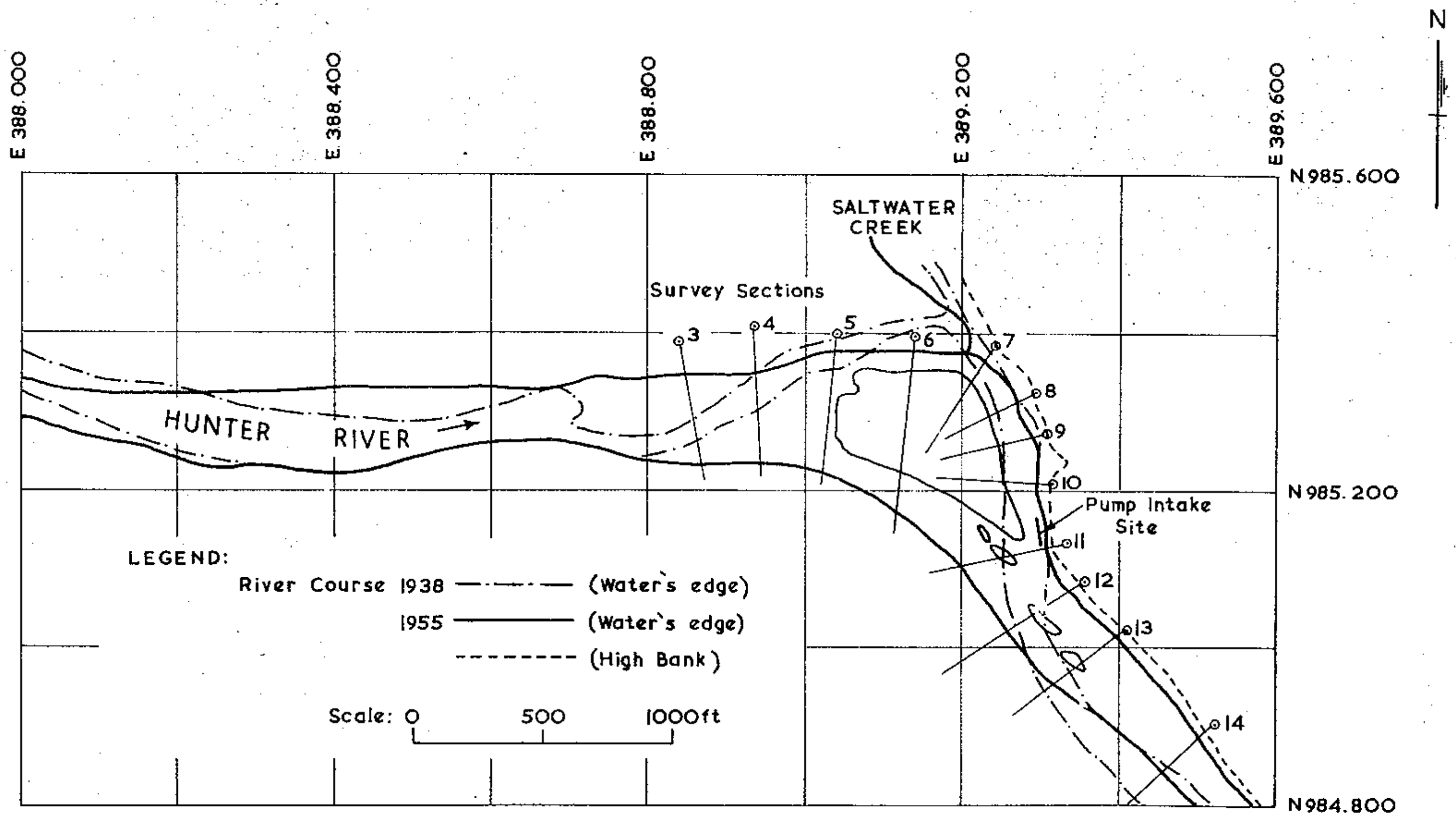


Figure 8: Hunter River in 1938 and in 1955.

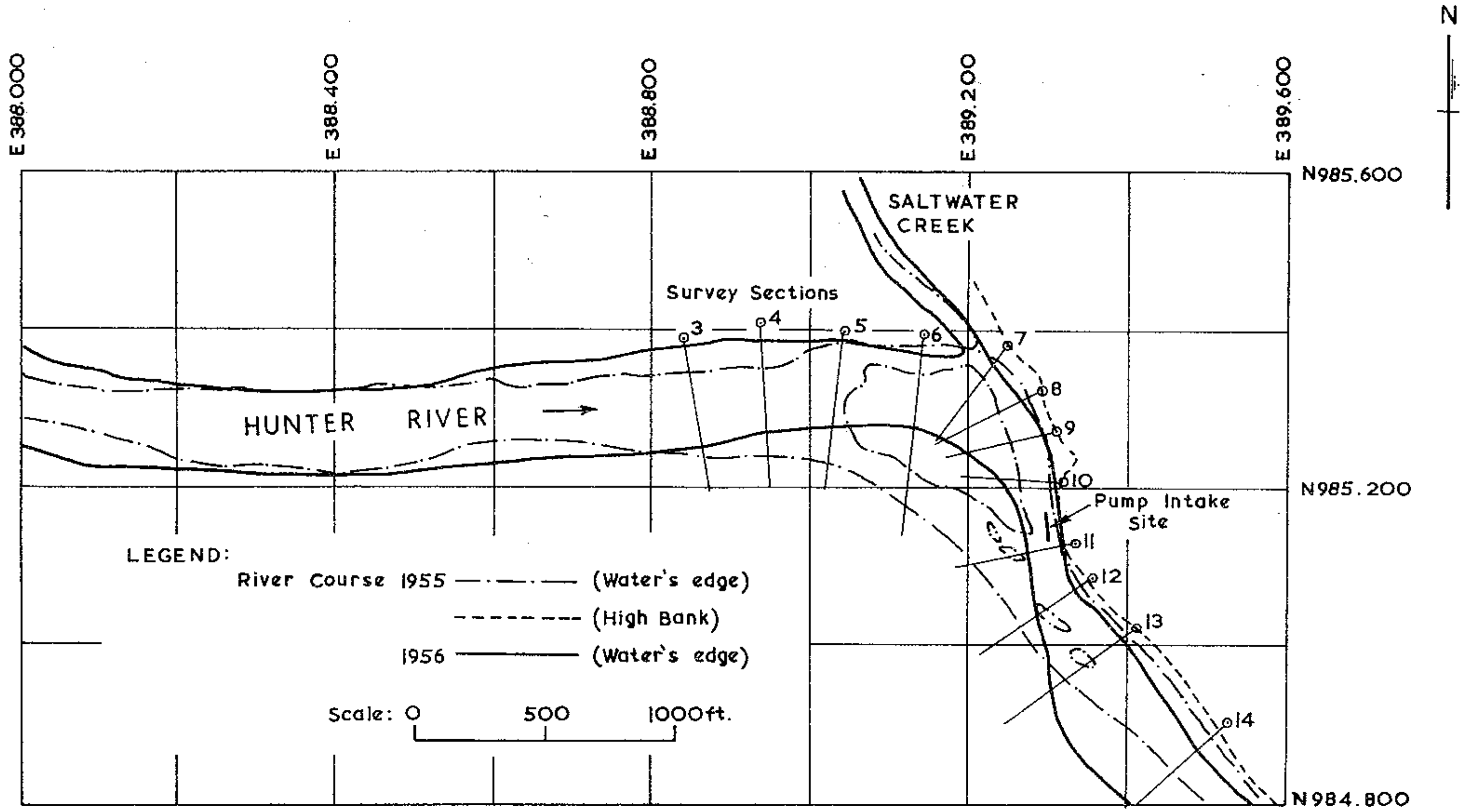


Figure 9: Hunter River in 1955 and in 1956.

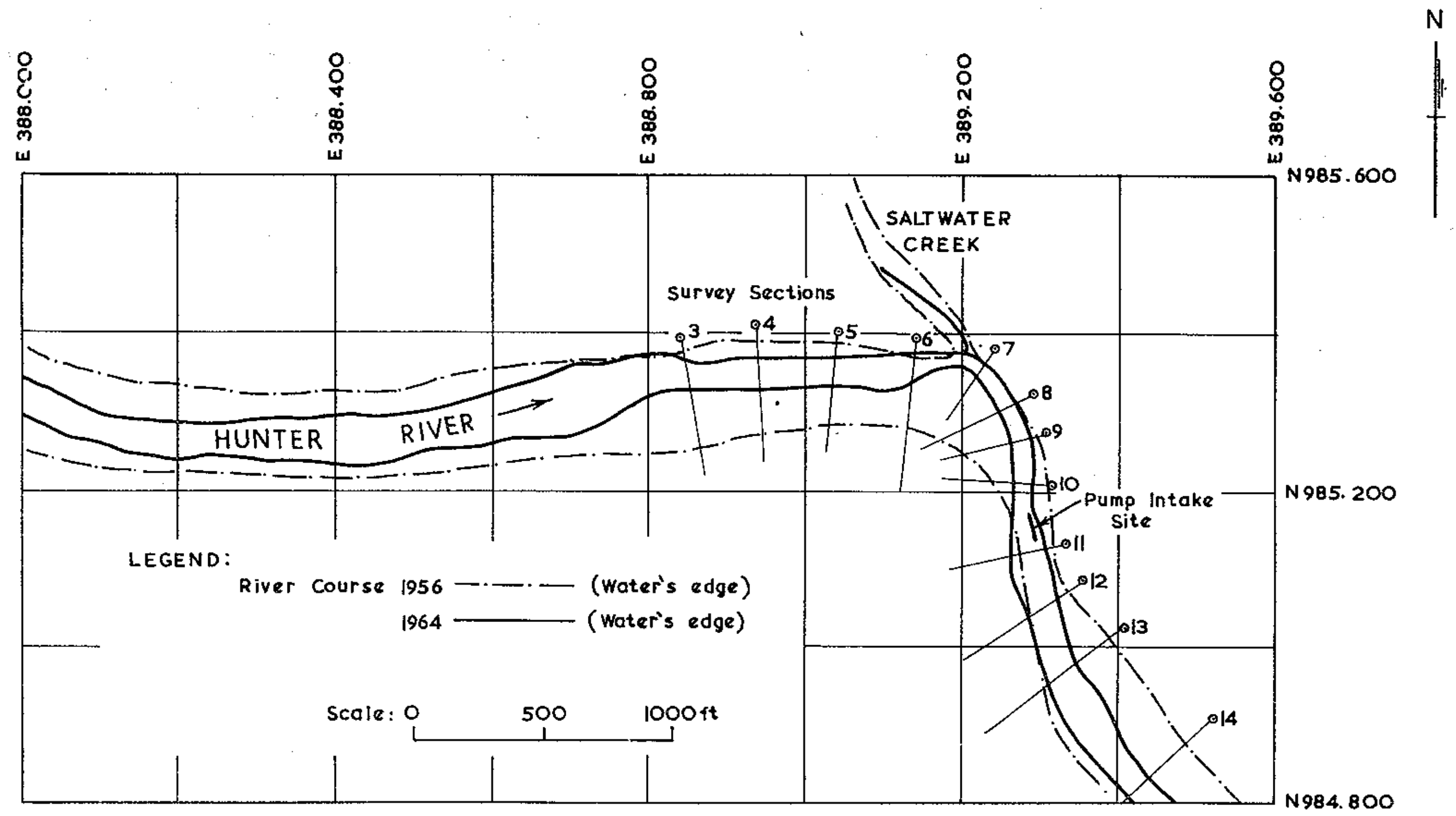


Figure 10: Hunter River in 1956 and in 1964.

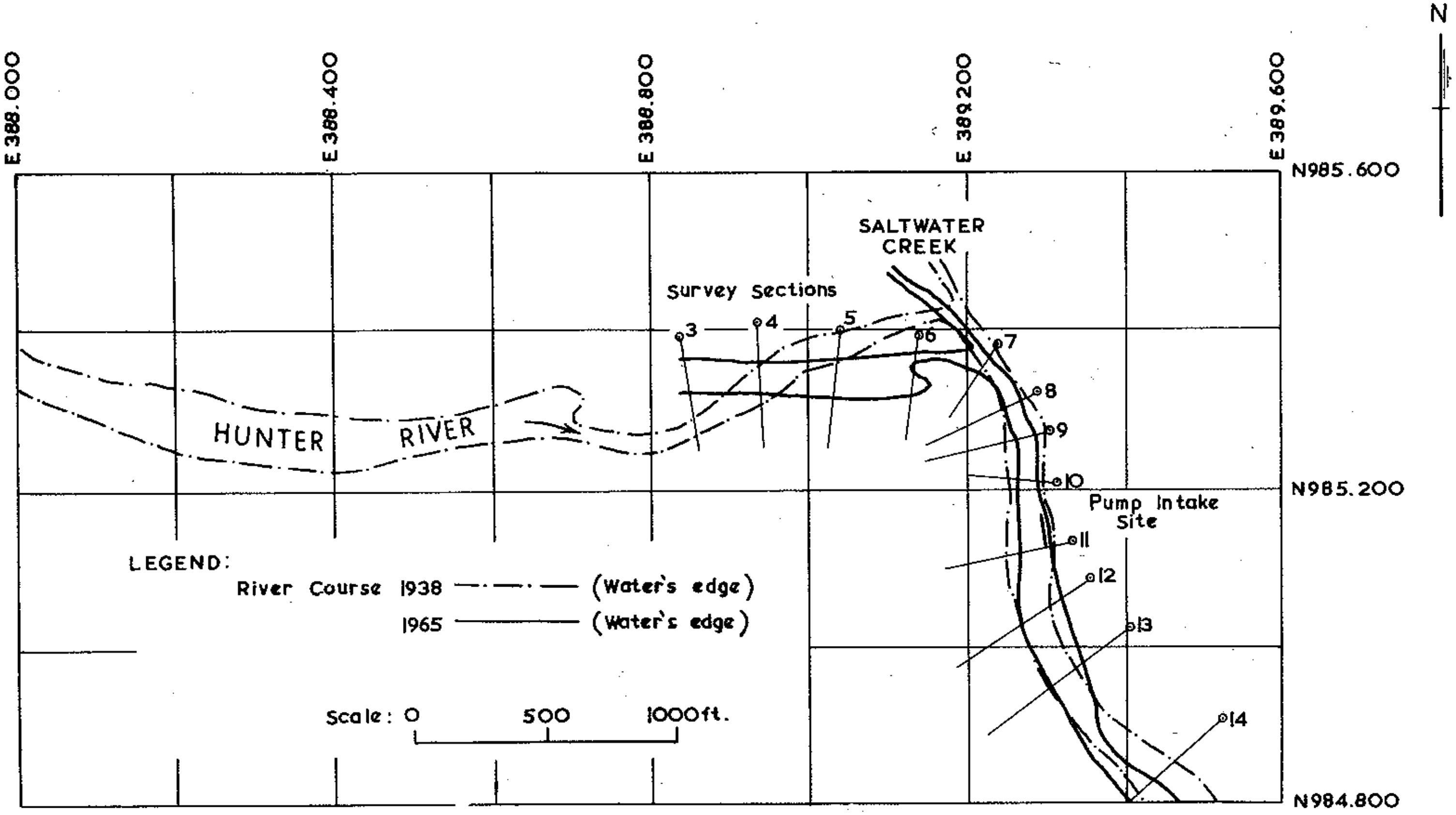


Figure 11: Hunter River in 1938 and in 1965.

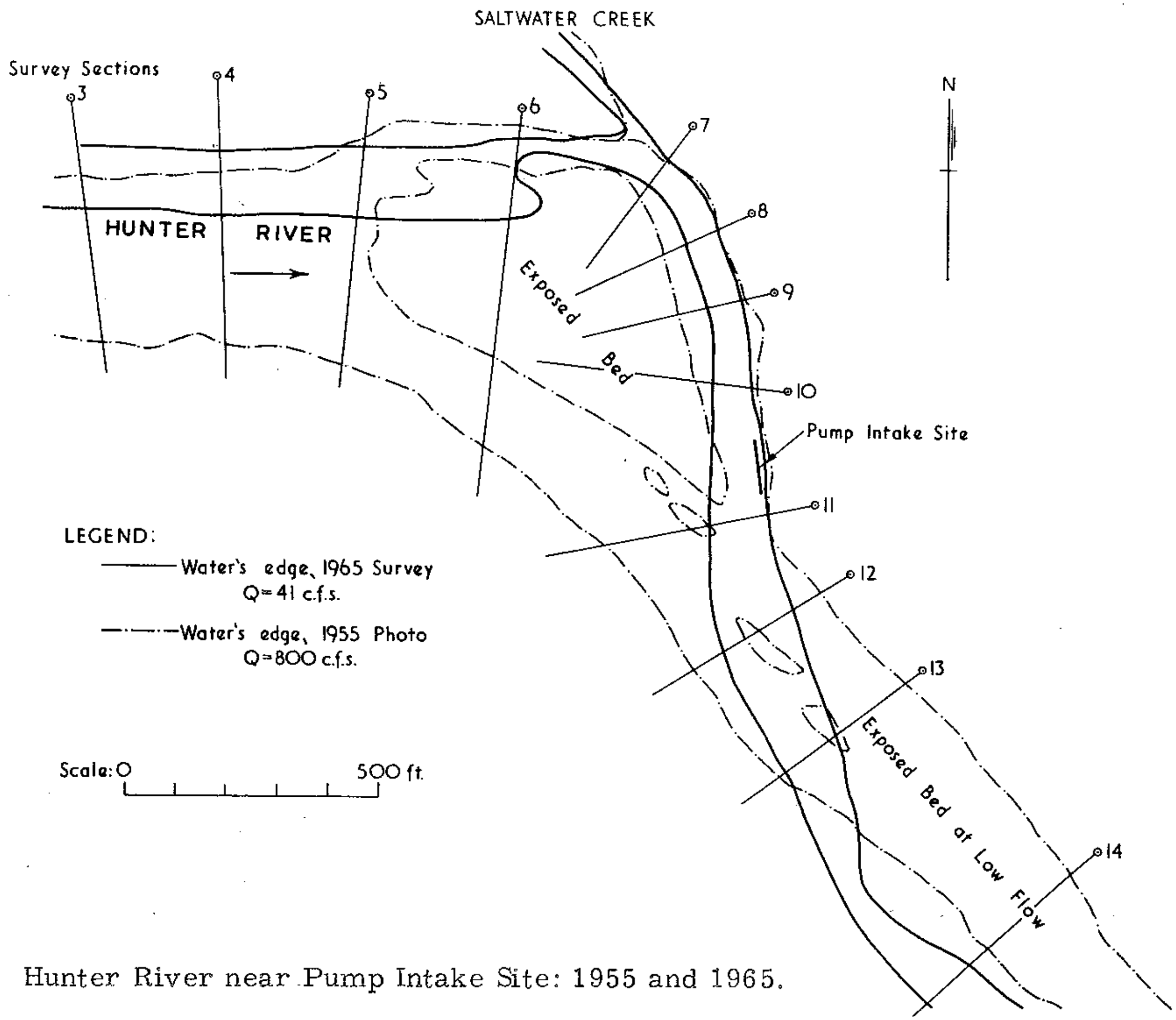
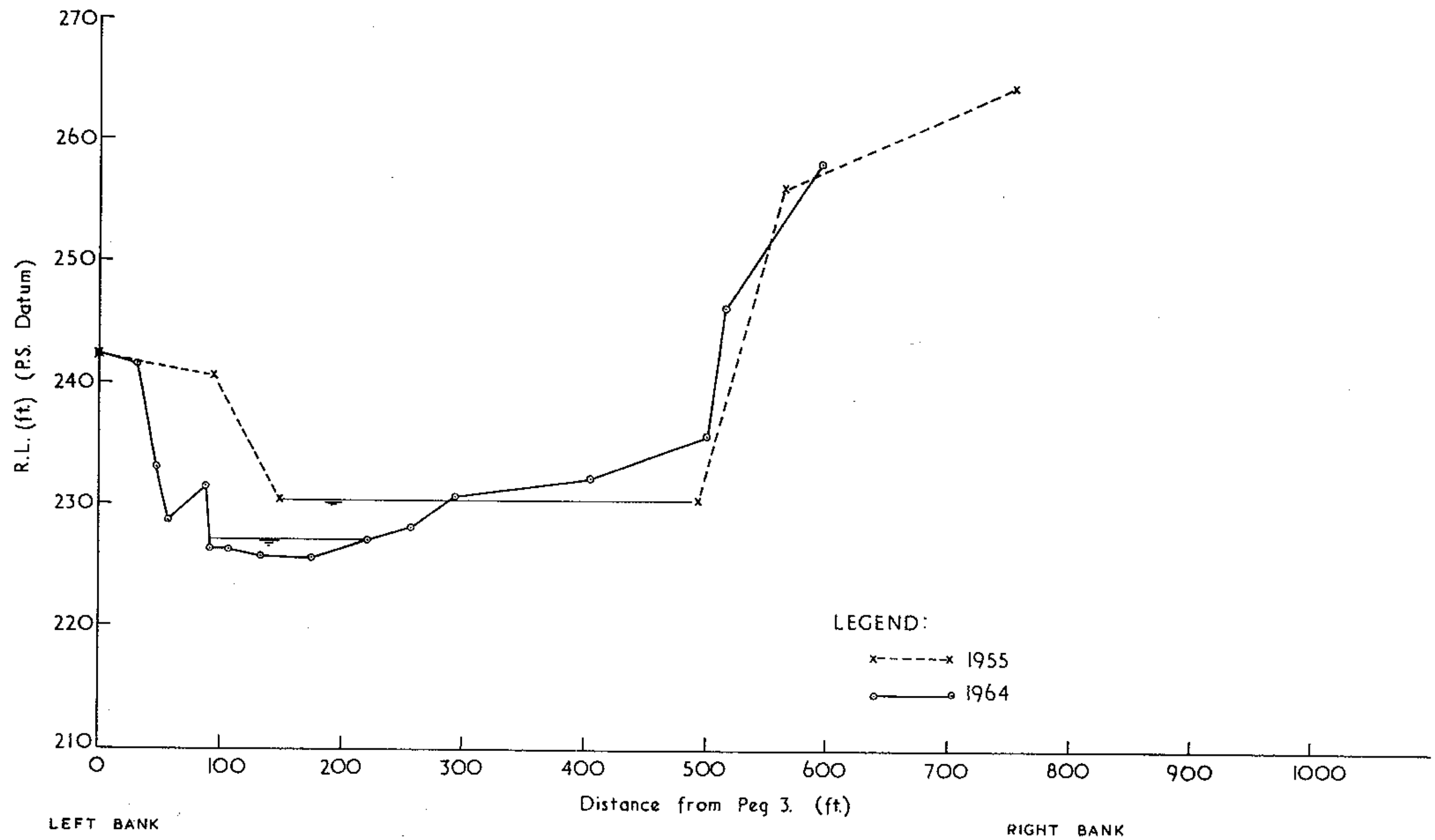
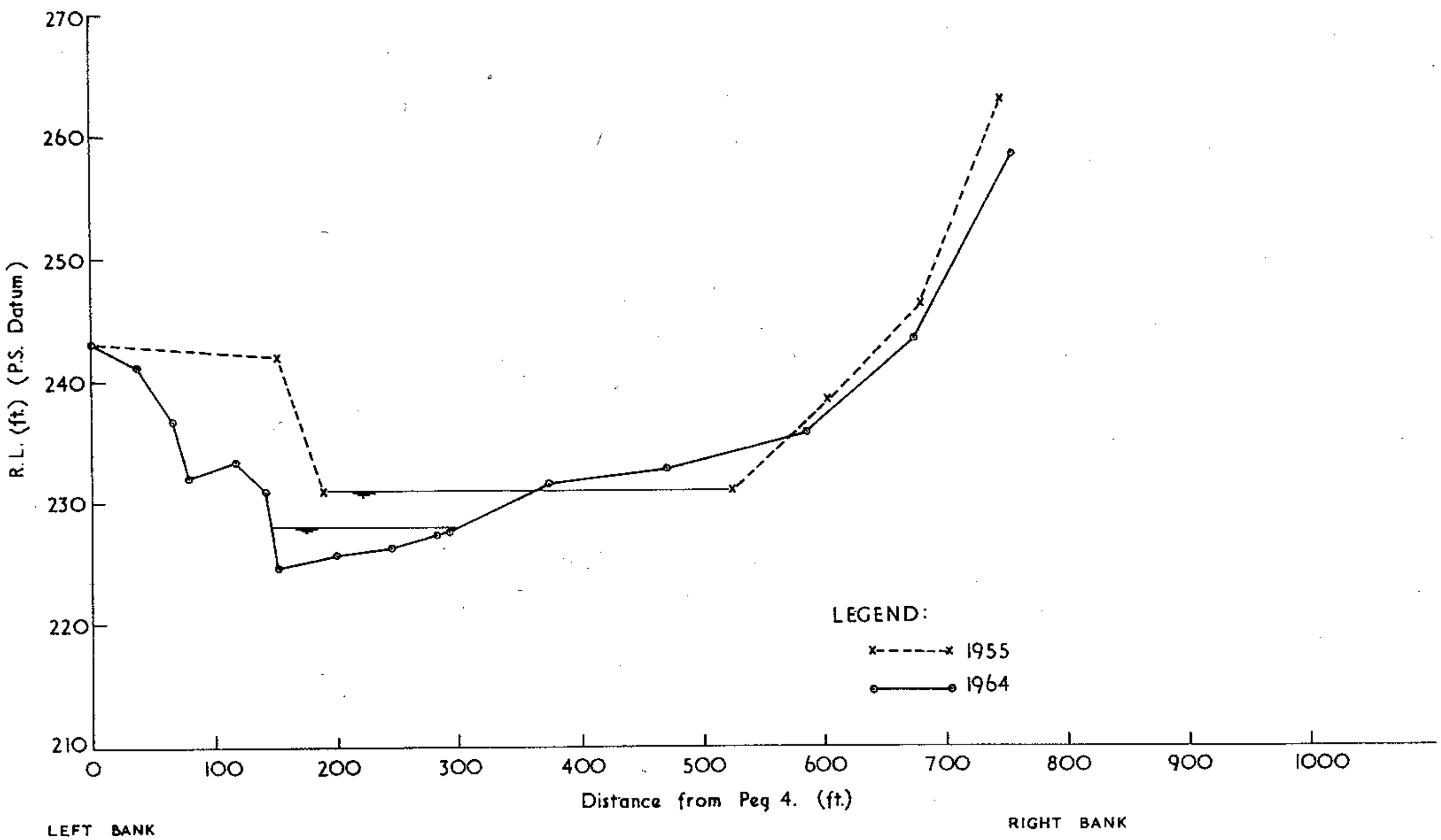


Figure 12: Hunter River near Pump Intake Site: 1955 and 1965.



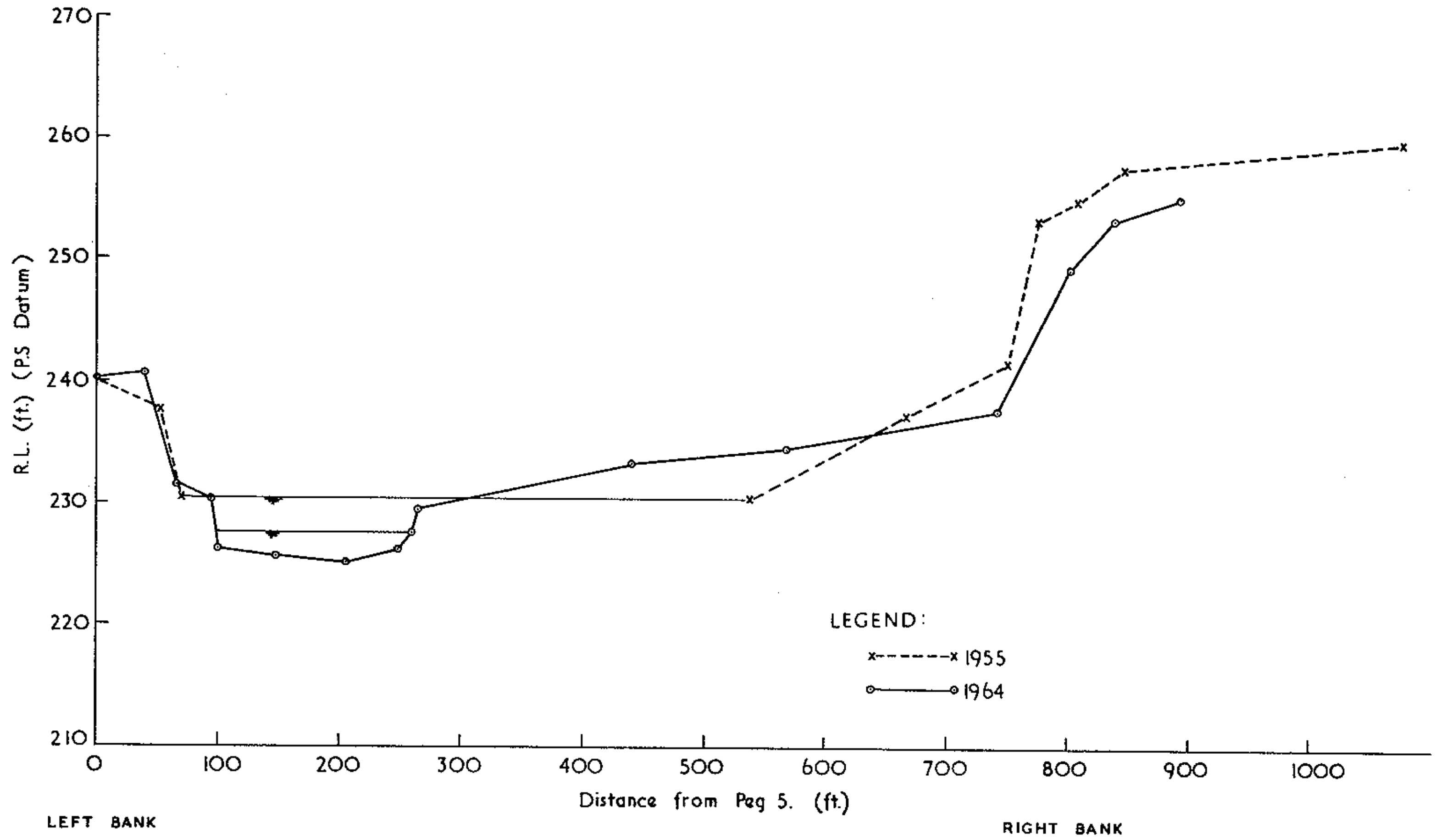
(a) Survey Section 3

Figure 13: River cross sections.



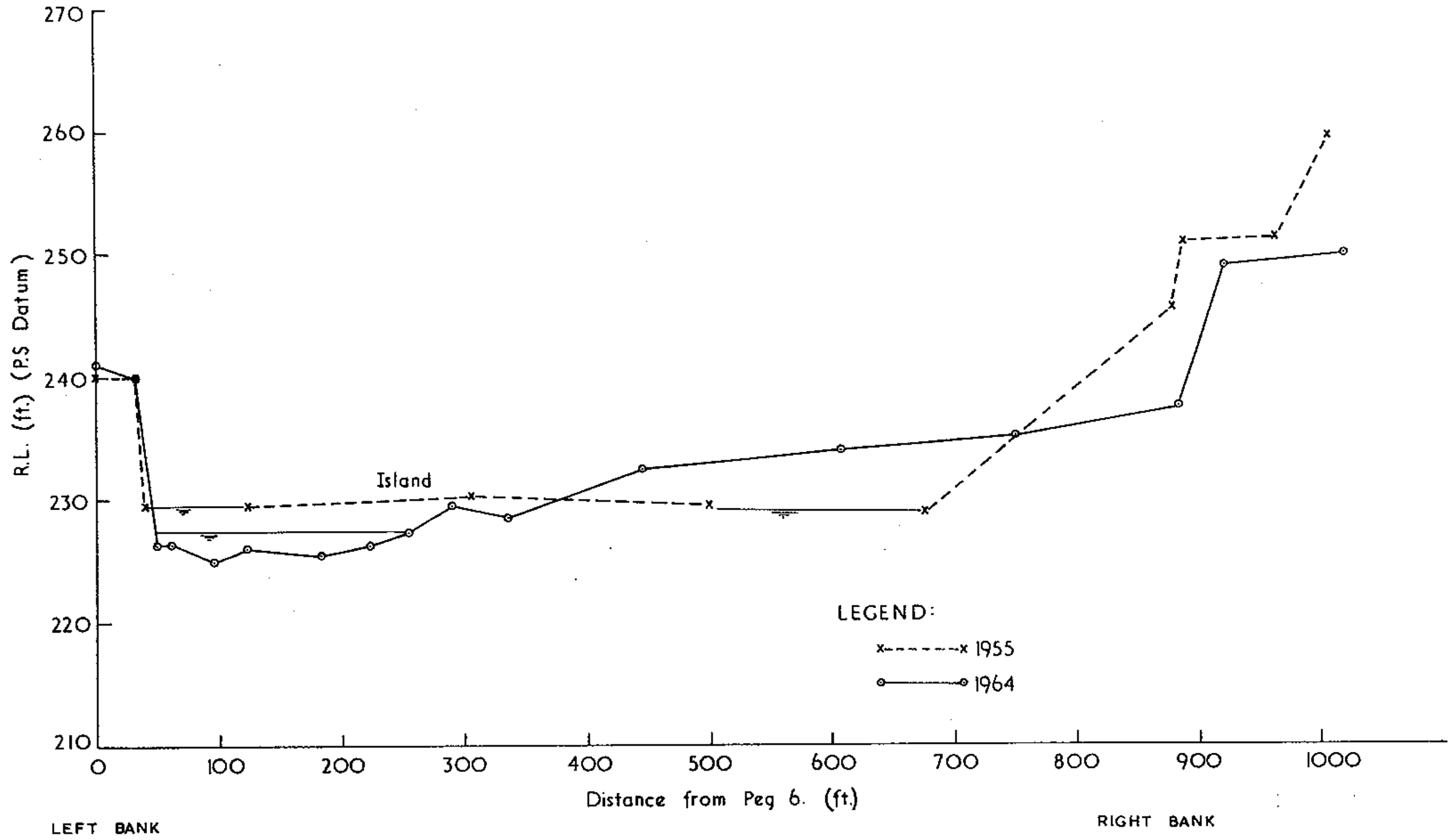
(b) Survey Section 4

Figure 13: River cross sections.



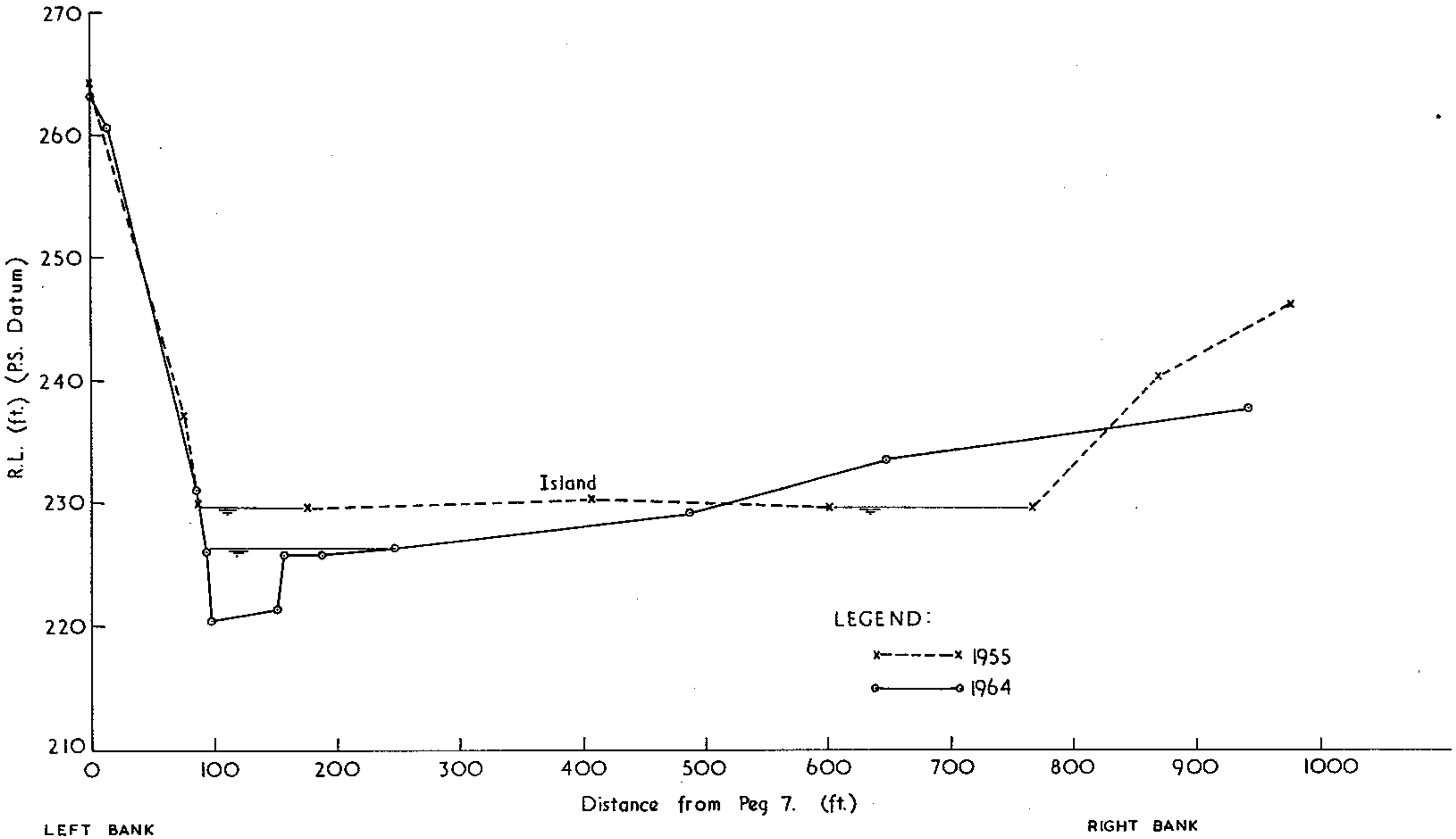
(c) Survey Section 5

Figure 13: River cross sections



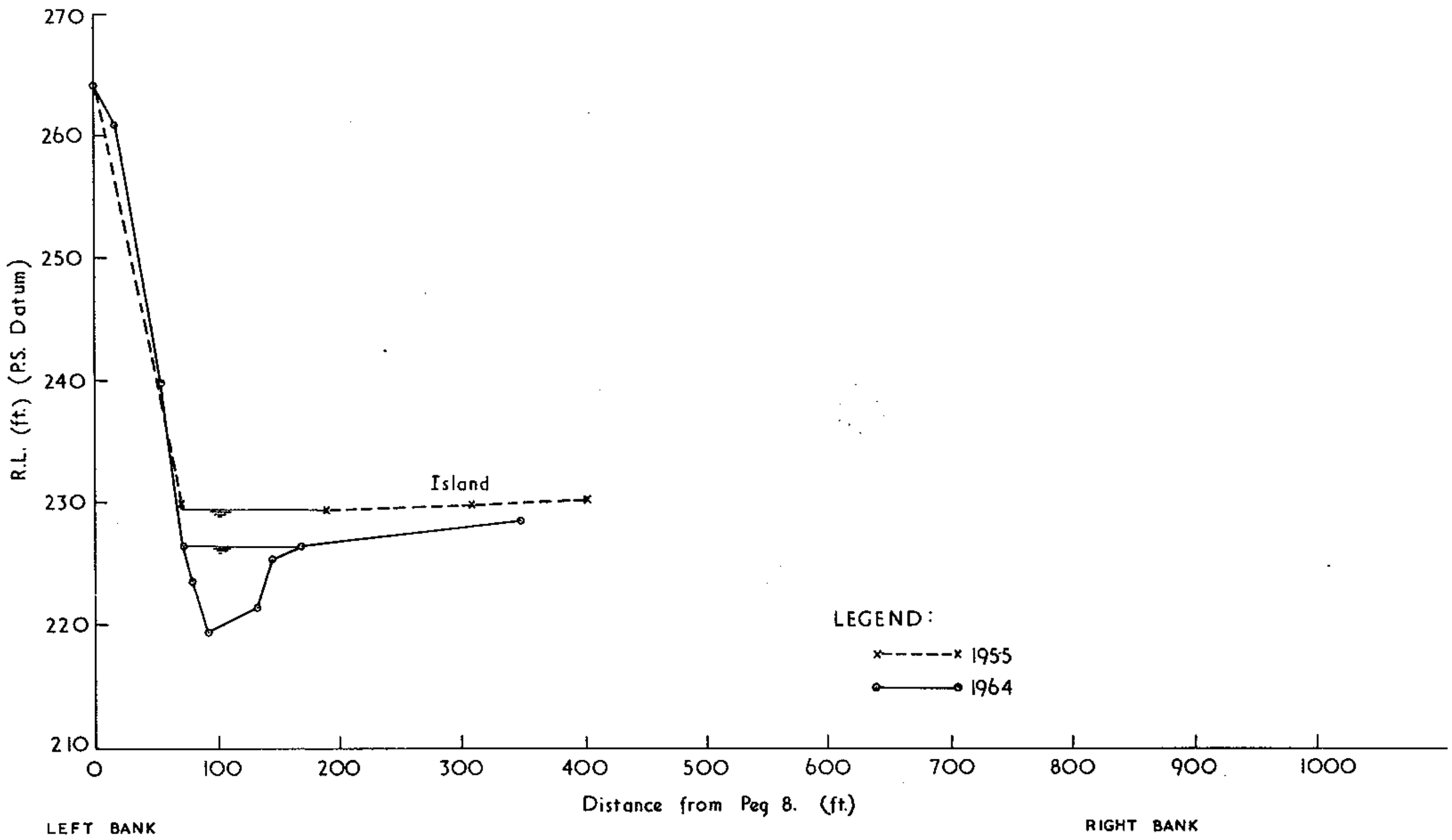
(d) Survey Section 6.

Figure 13: River cross sections.



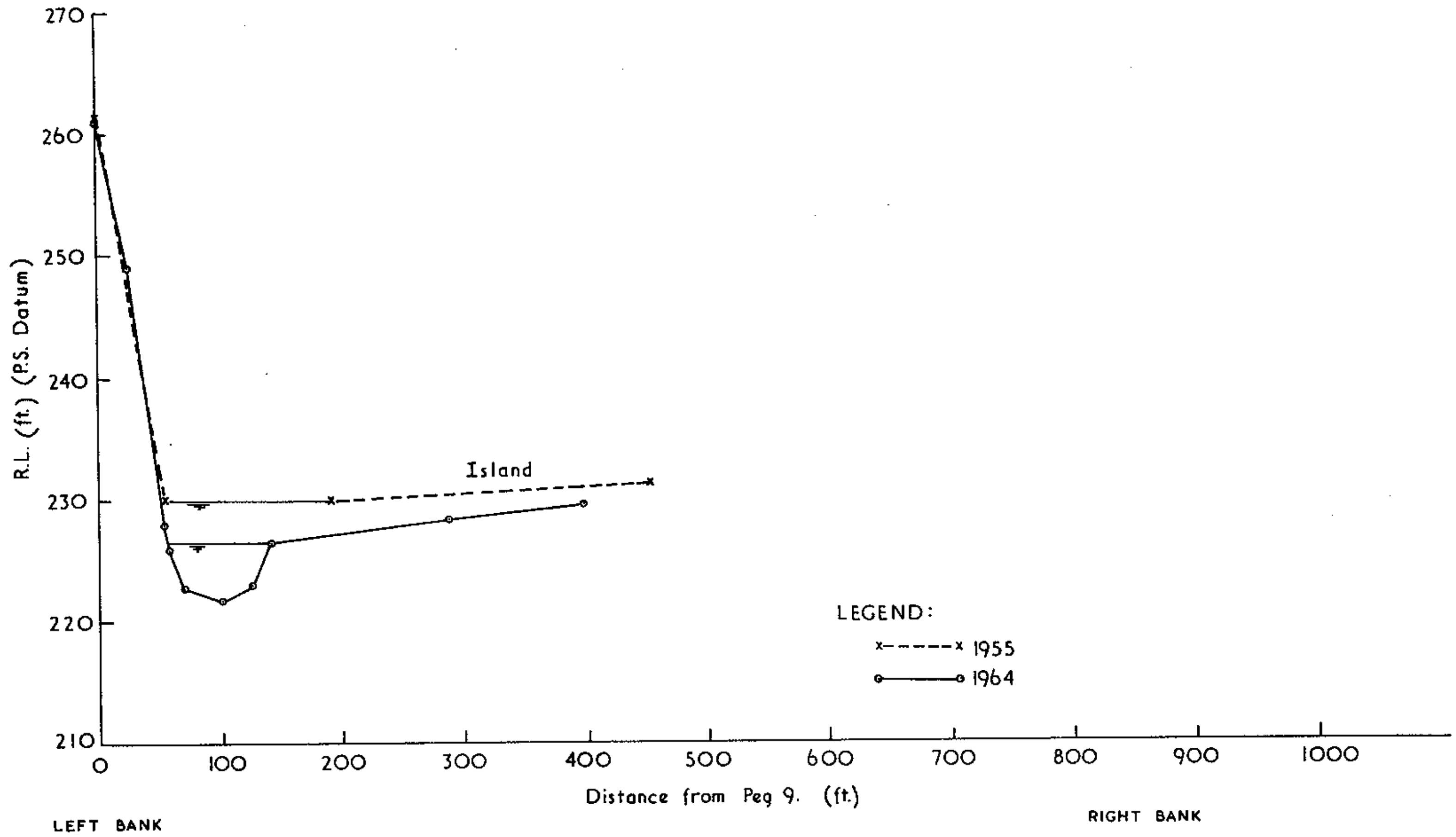
(e) Survey Section 7

Figure 13: River cross sections.



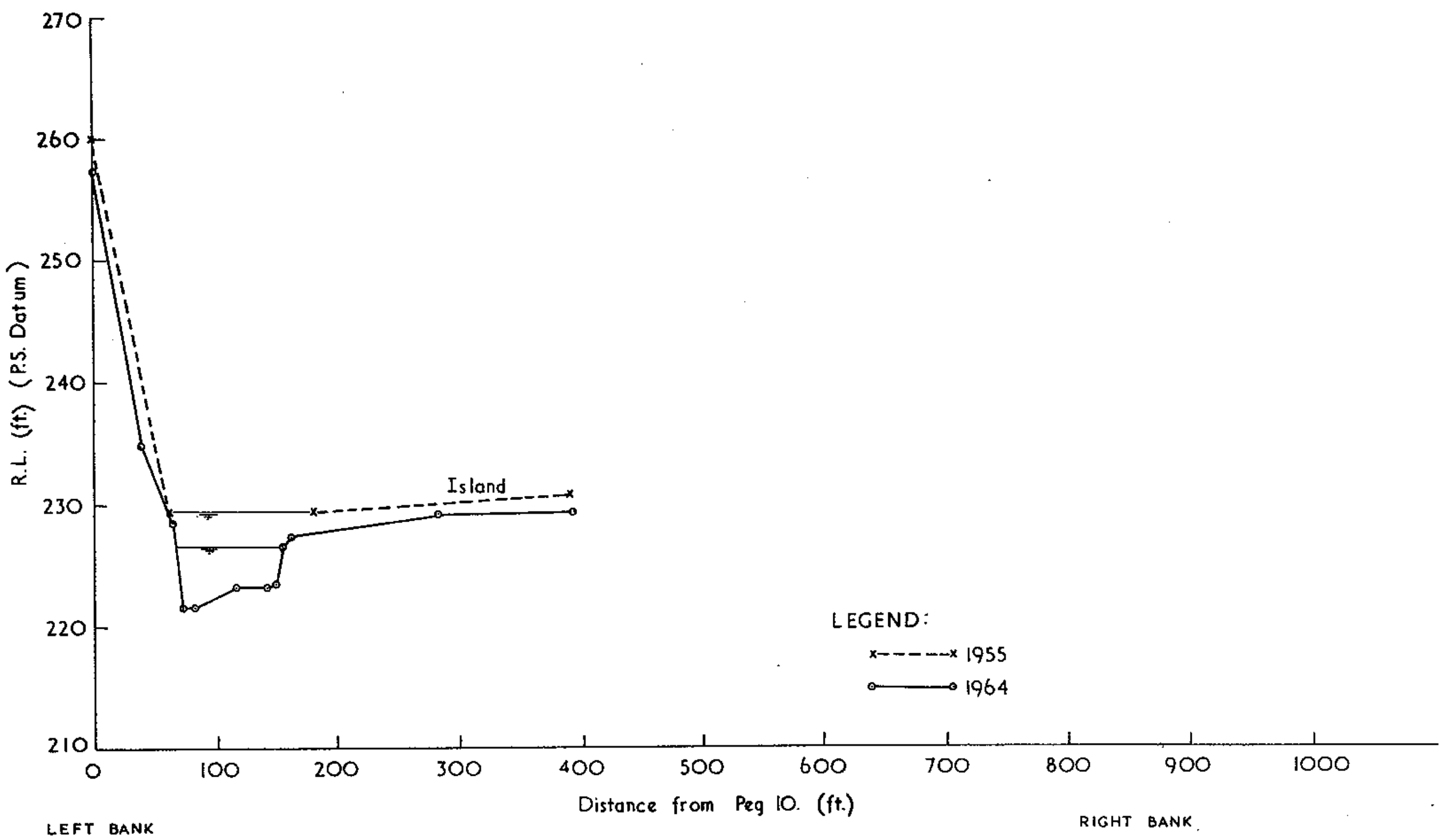
(f) Survey Section 8

Figure 13: River cross sections.



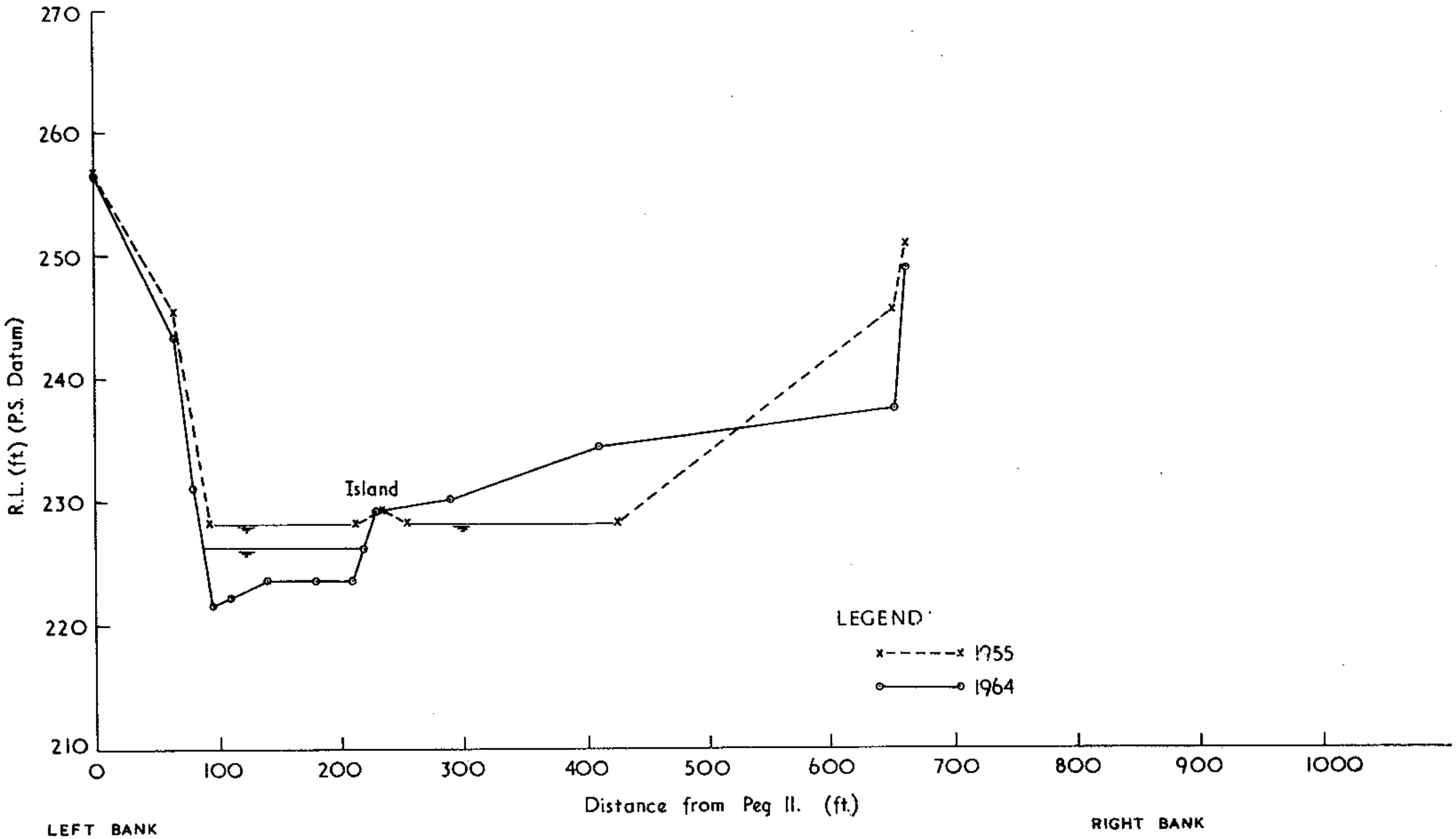
(g) Survey Section 9.

Figure 13: River cross sections.



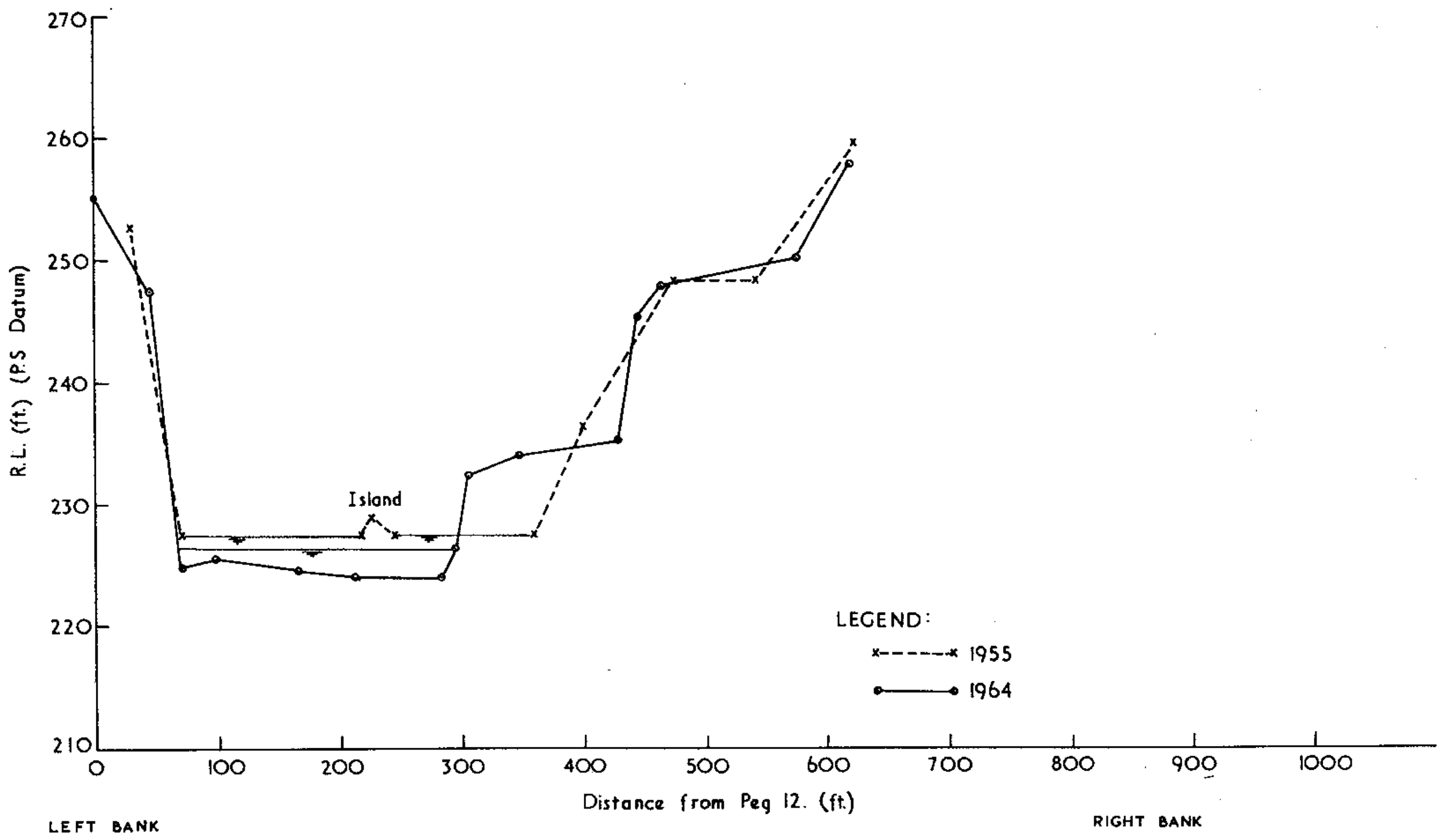
(h) Survey Section 10.

Figure 13: River cross sections.



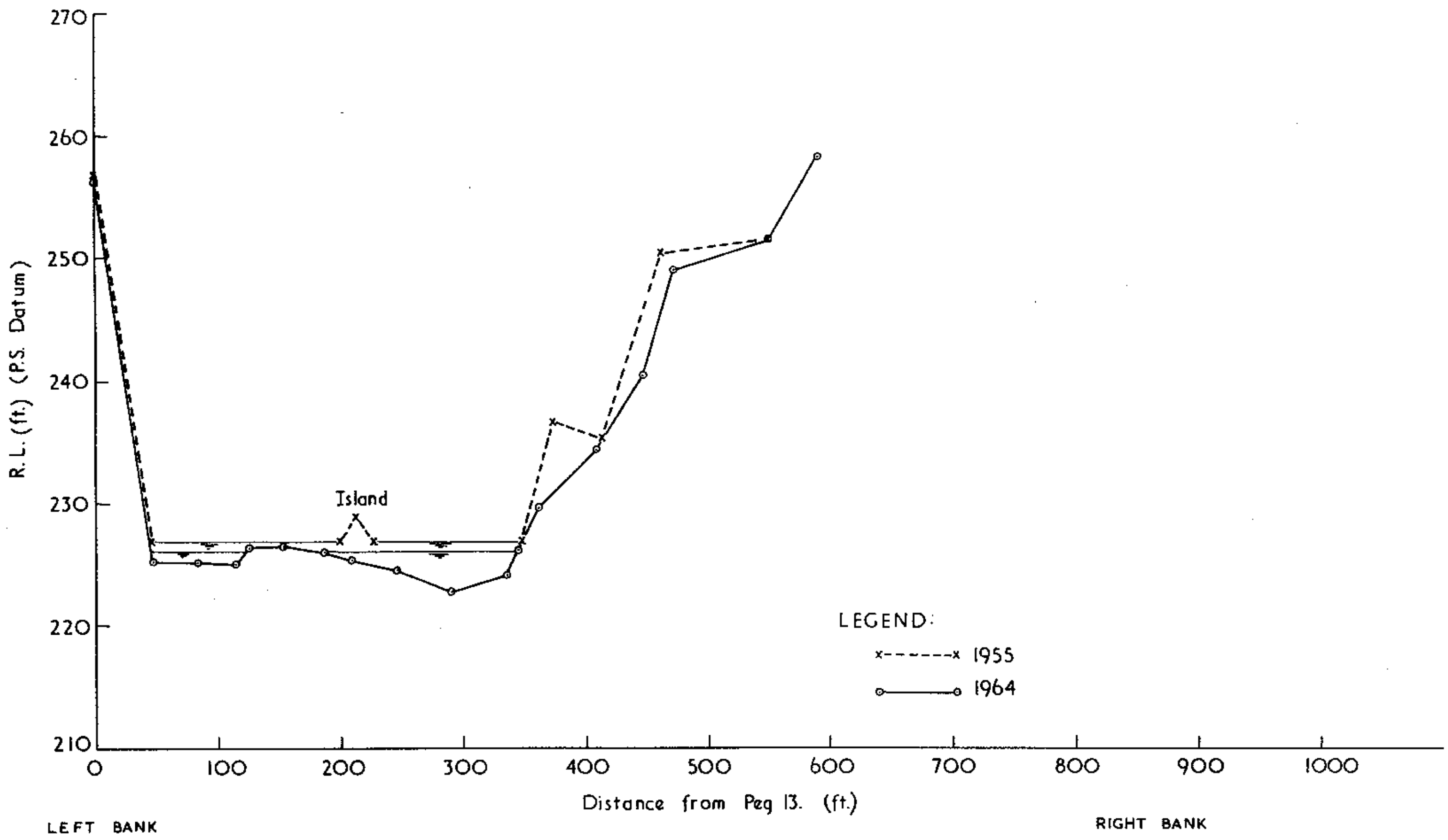
(i) Survey Section 11

Figure 13: River cross sections.



(j) Survey Section 12

Figure 13: River cross sections.



(k) Survey Section 13

Figure 13. River cross sections.

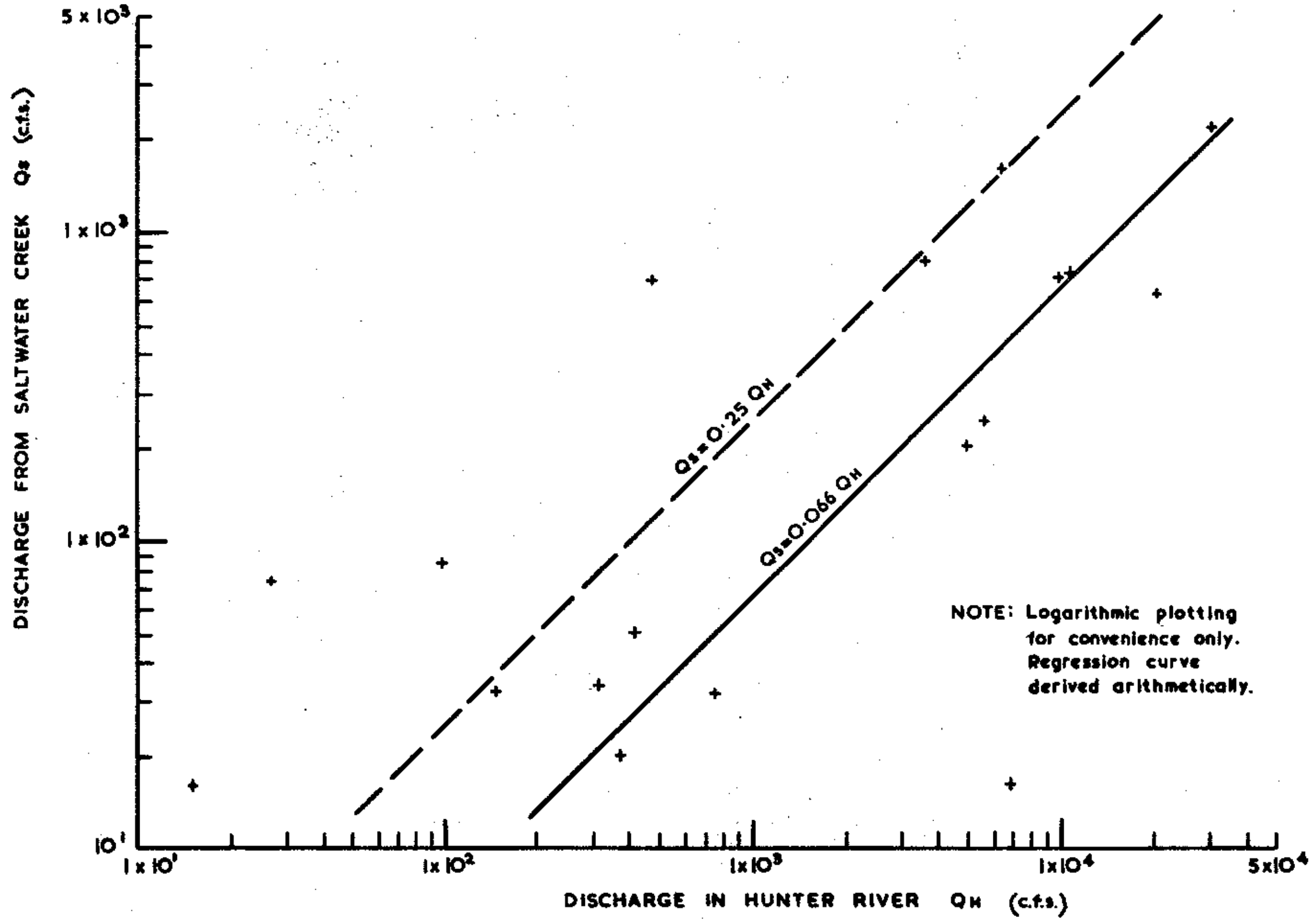


Figure 14: Relationship of discharges from Saltwater Creek and in the Hunter River.

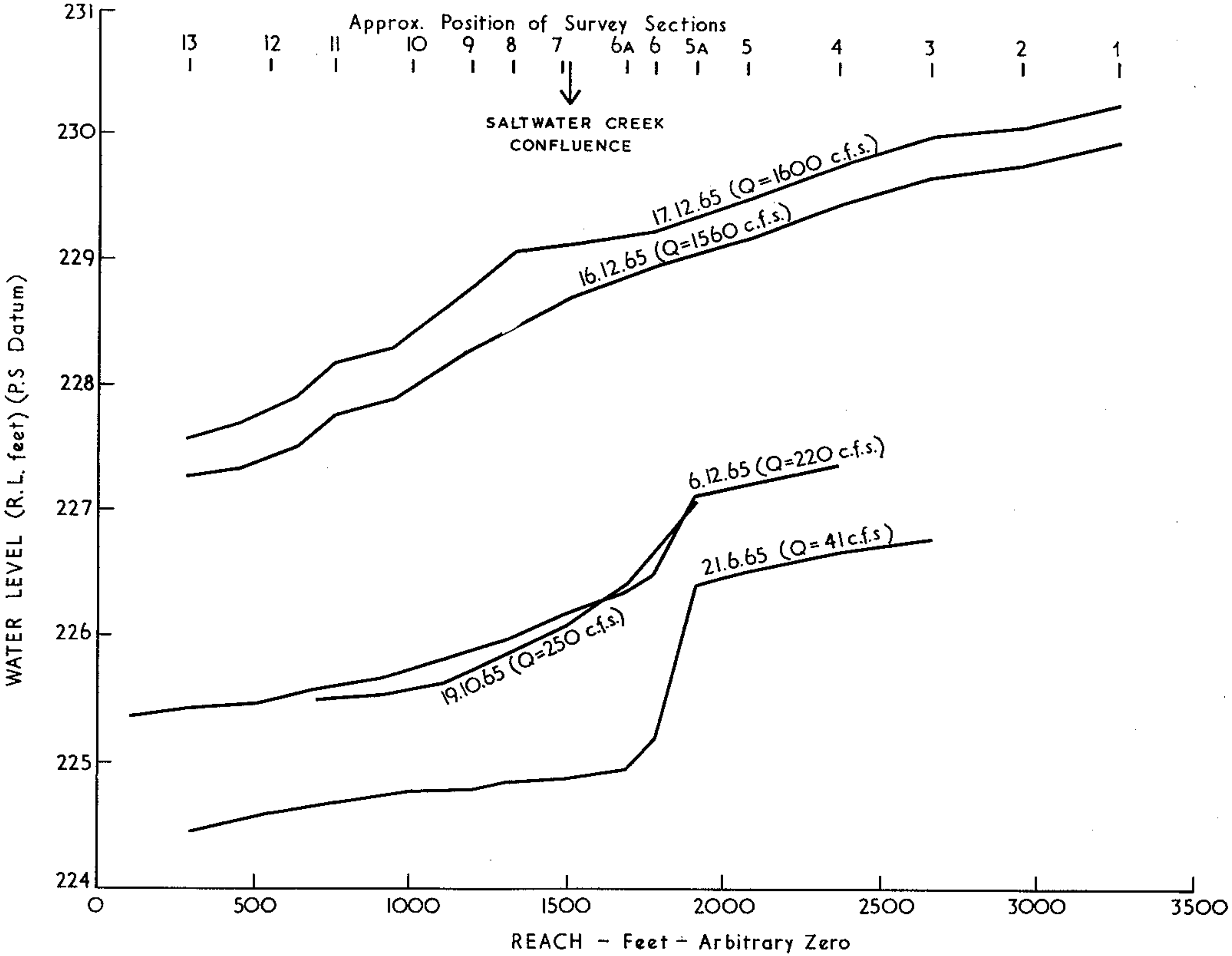


Figure 15; River surface profile (left bank).

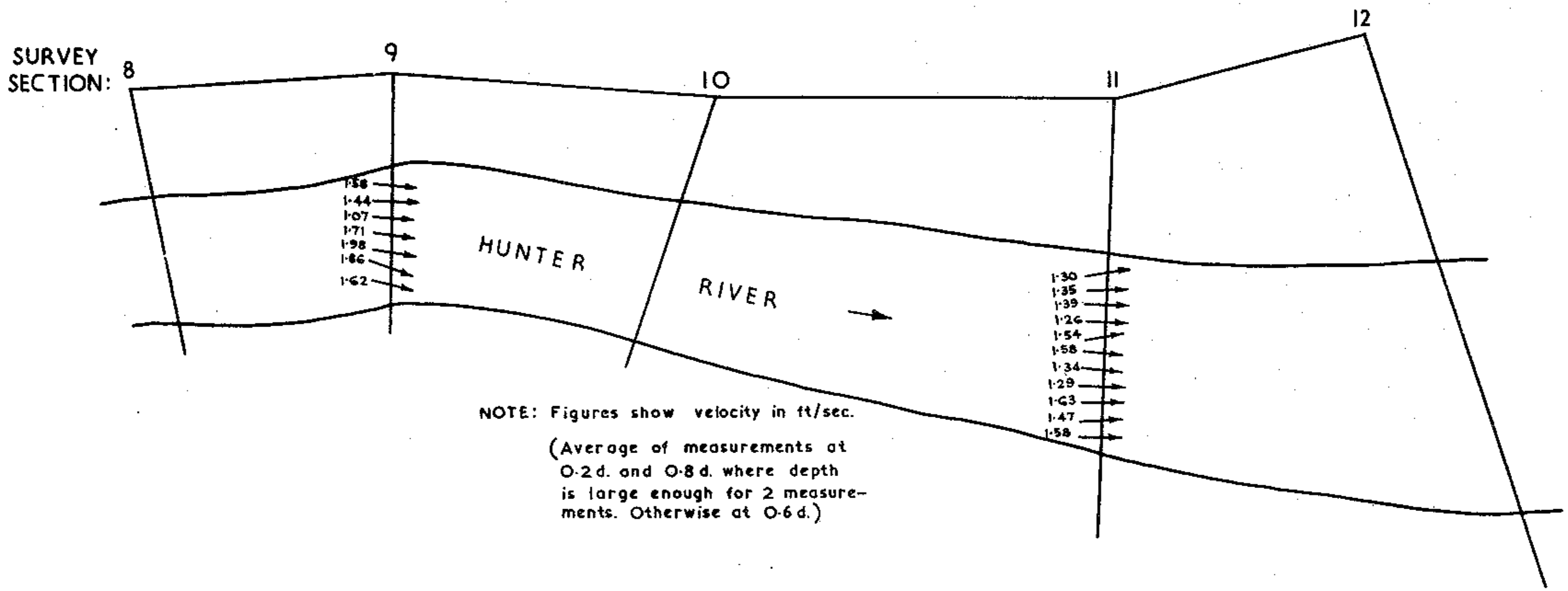


Figure 16: Velocity magnitude and direction in the Hunter River.

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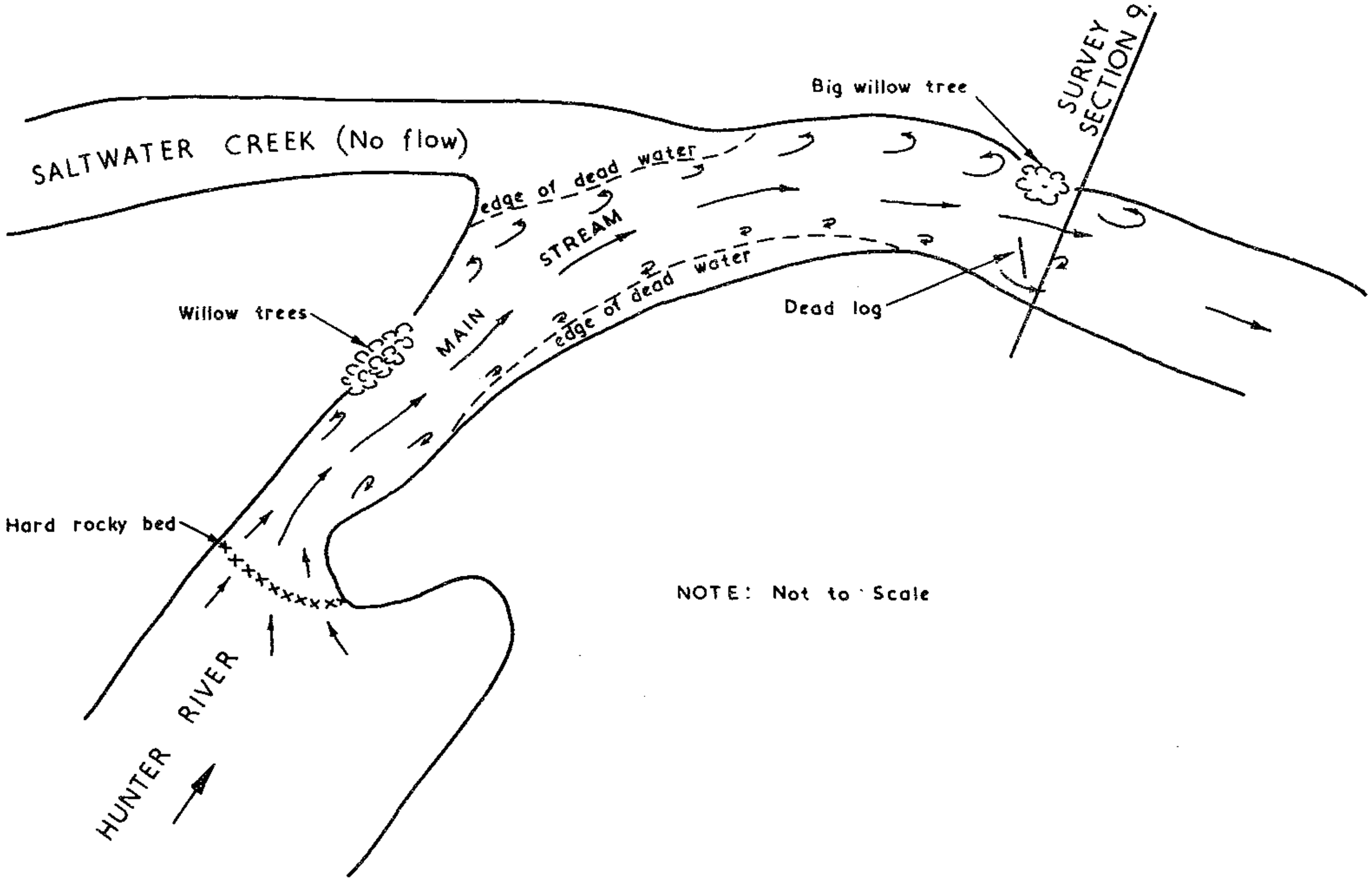
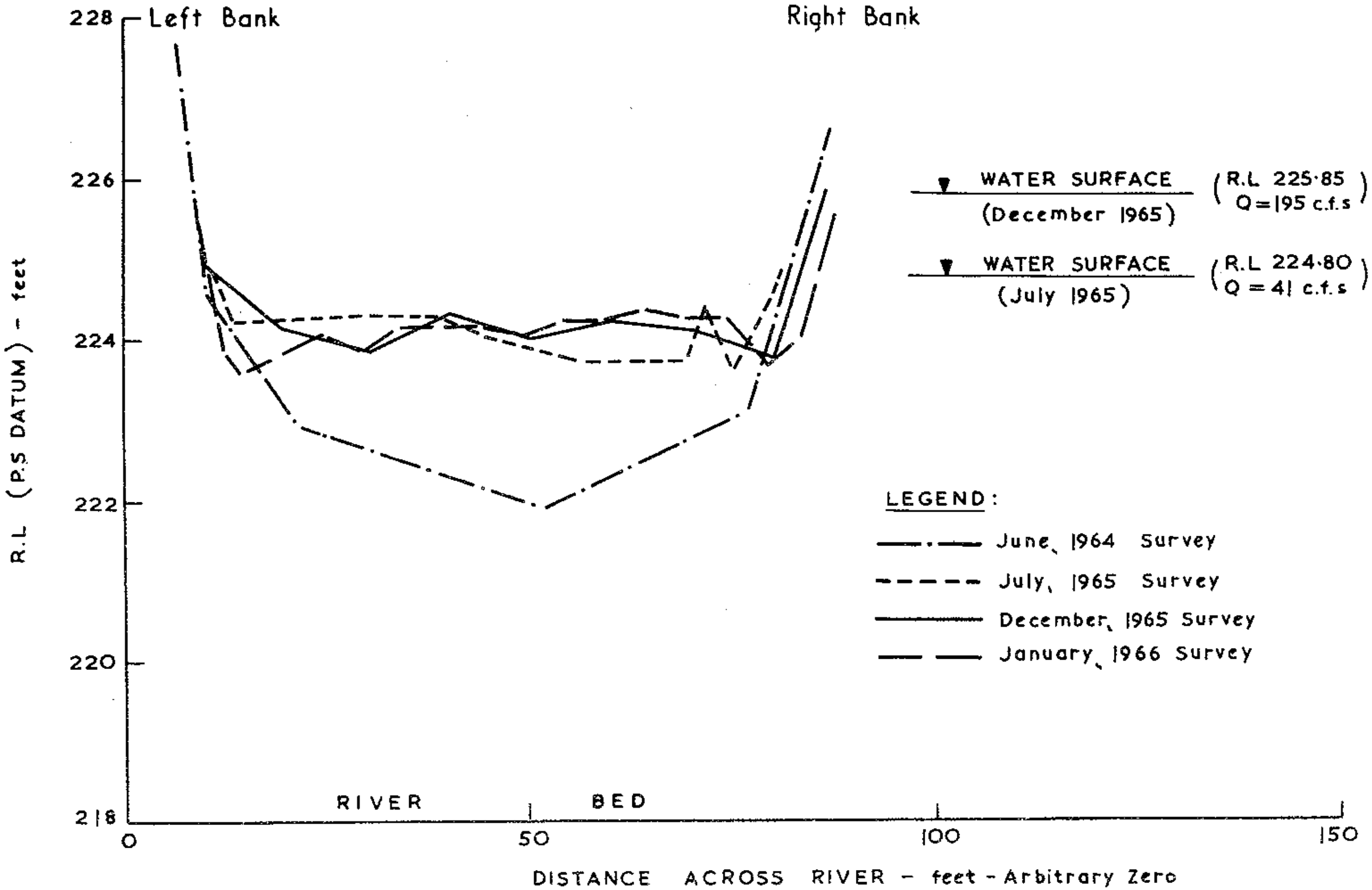
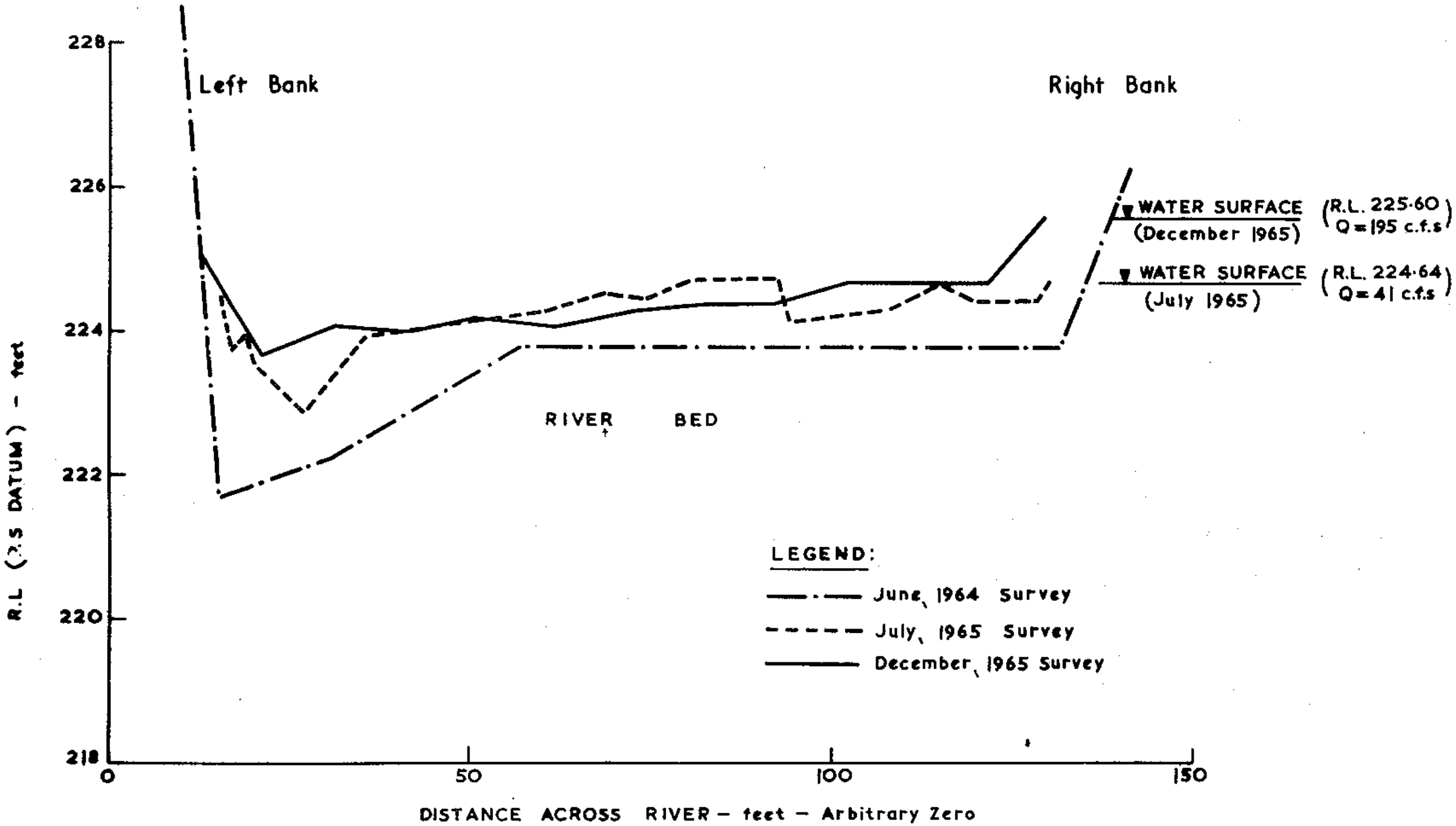


Figure 17: Flow pattern of the Hunter River near the confluence with Saltwater Creek.



(a) SURVEY SECTION 9.

Figure 18: Changes in river bed.



(b) SURVEY SECTION 11.

Figure 18: Changes in river bed.

CE-E-6602

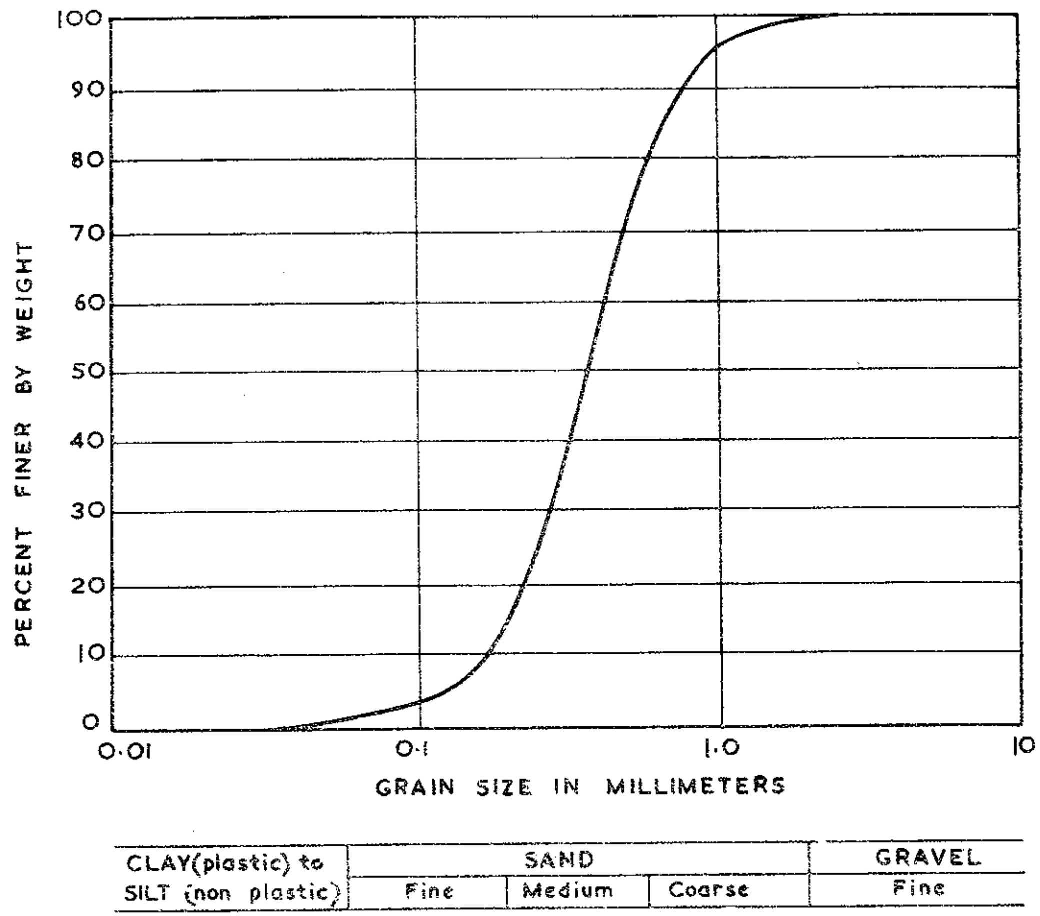


Figure 19: Size grading of sand and silt deposit at Site 2.

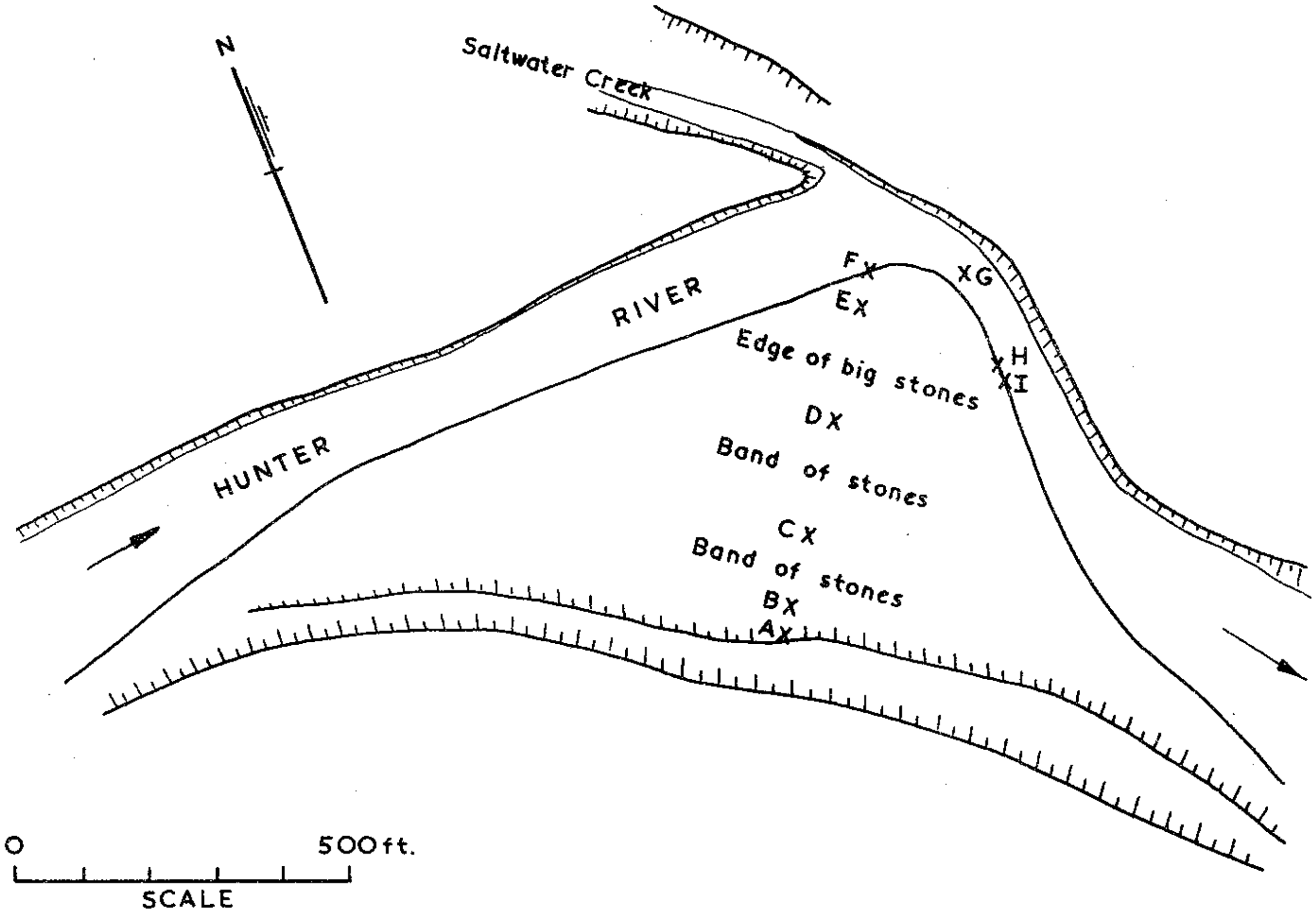


Figure 20: Location of bed sample collection.

CE-E-6289

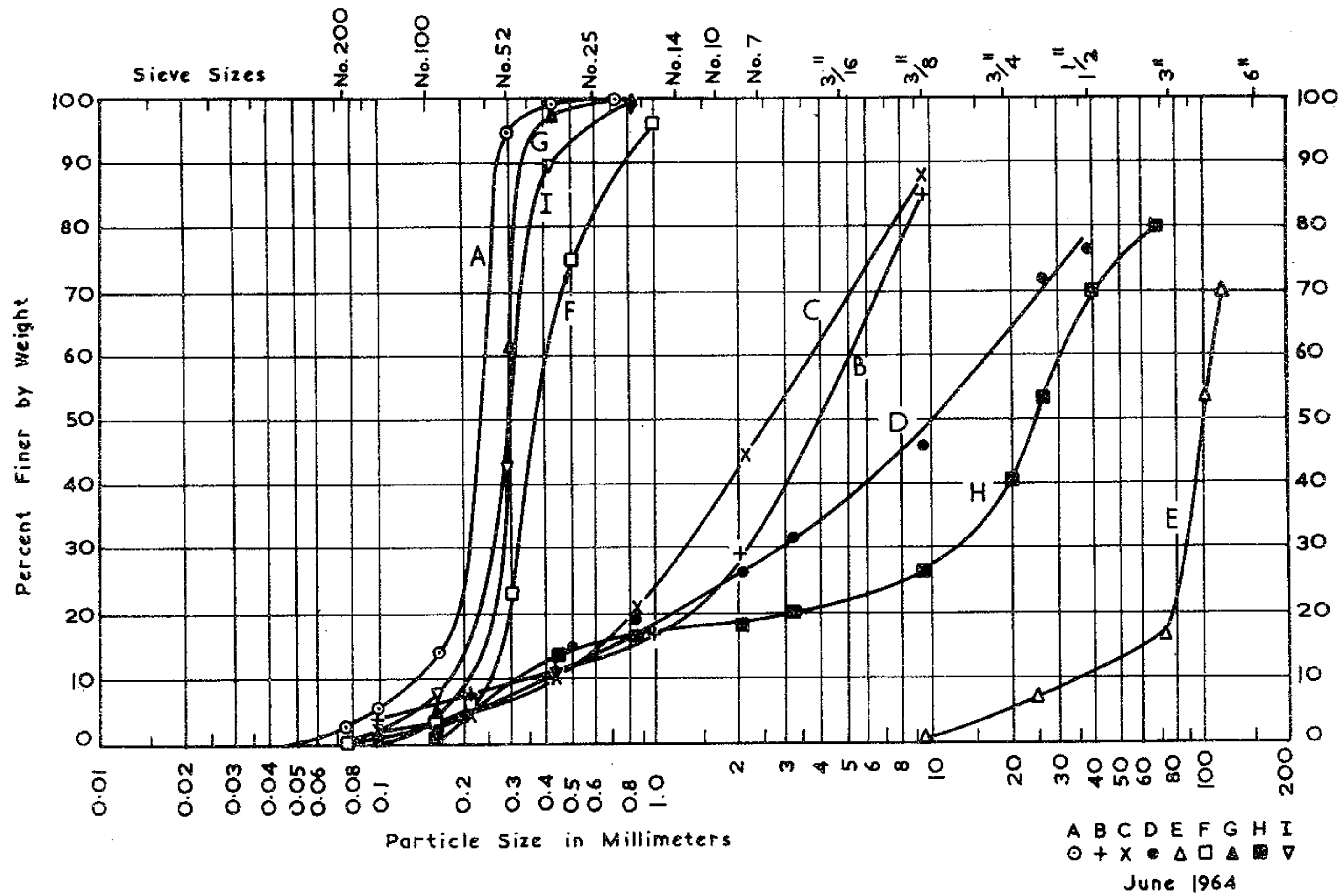


Figure 21: Size grading of bed samples.

CE-E-6290

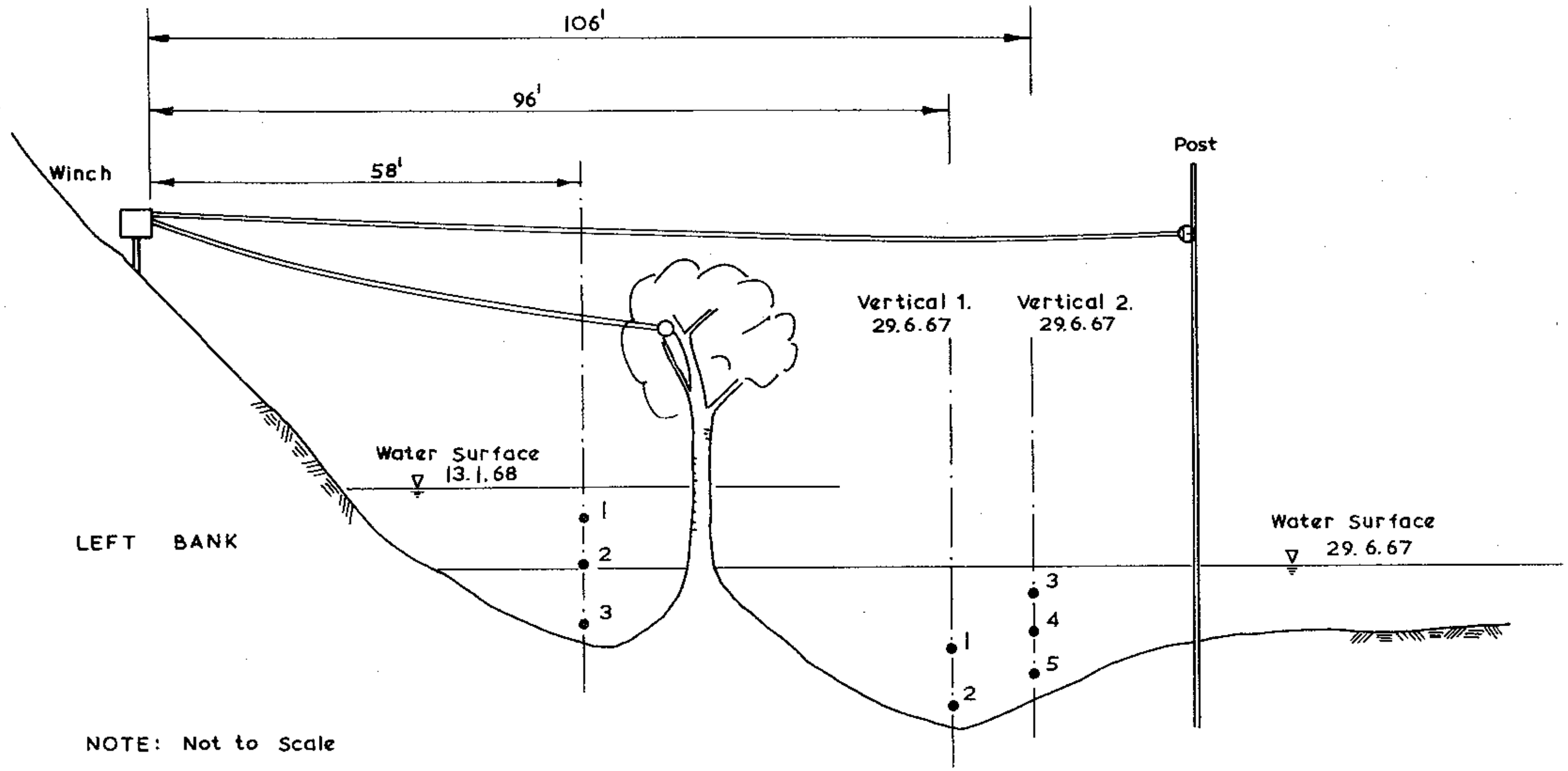


Figure 22: Location and set-up of suspended sampling apparatus.

CE-E-7317

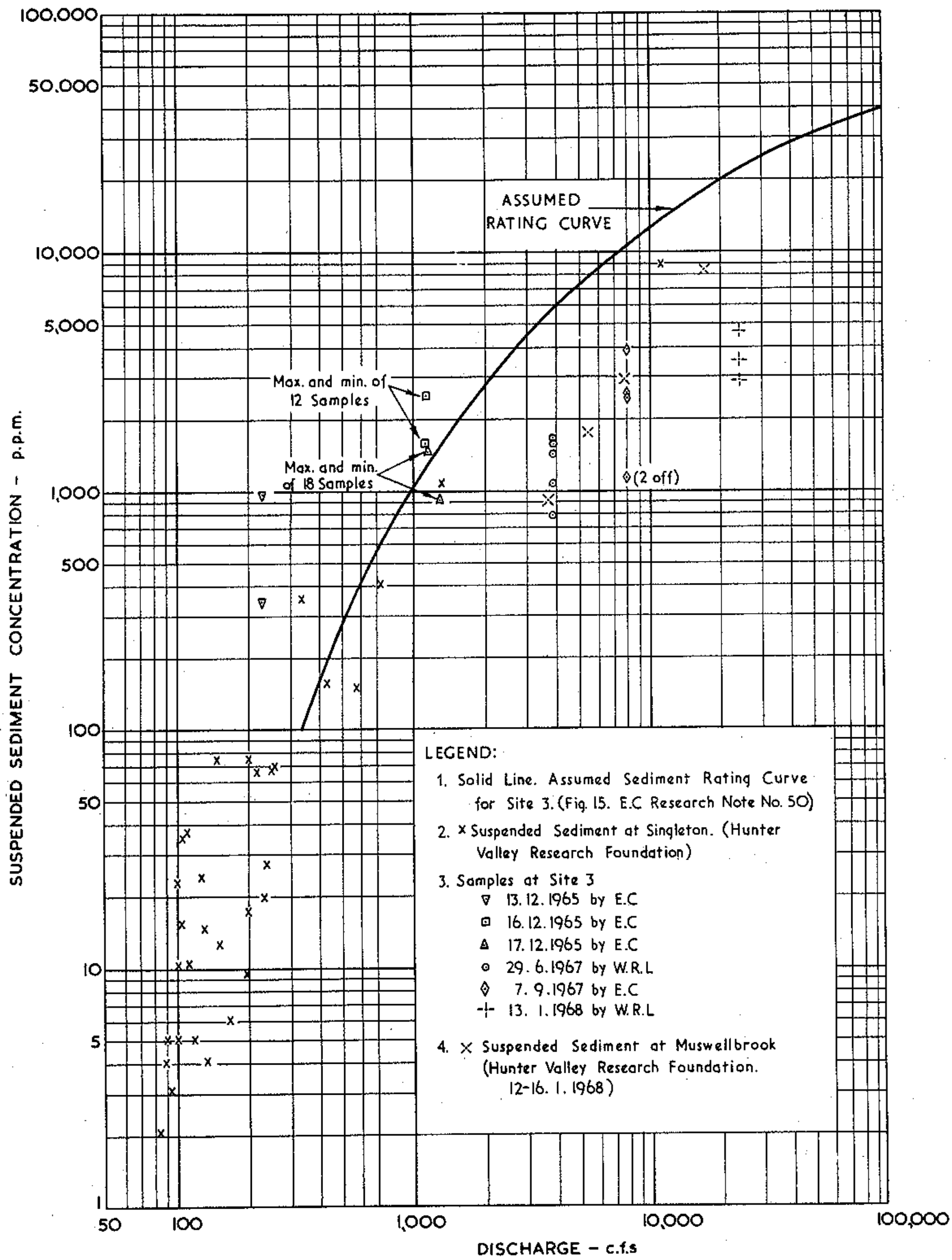


Figure 23: Suspended Sediment concentration.

CE-D-7318

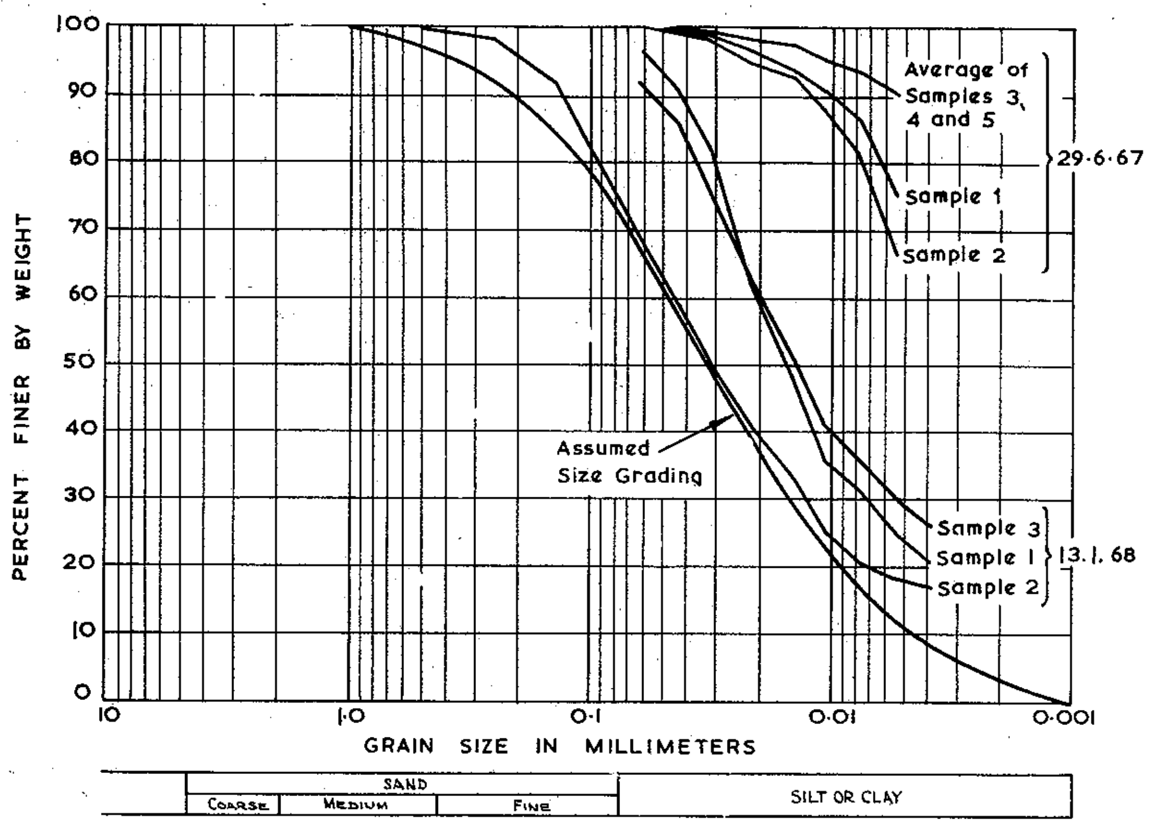
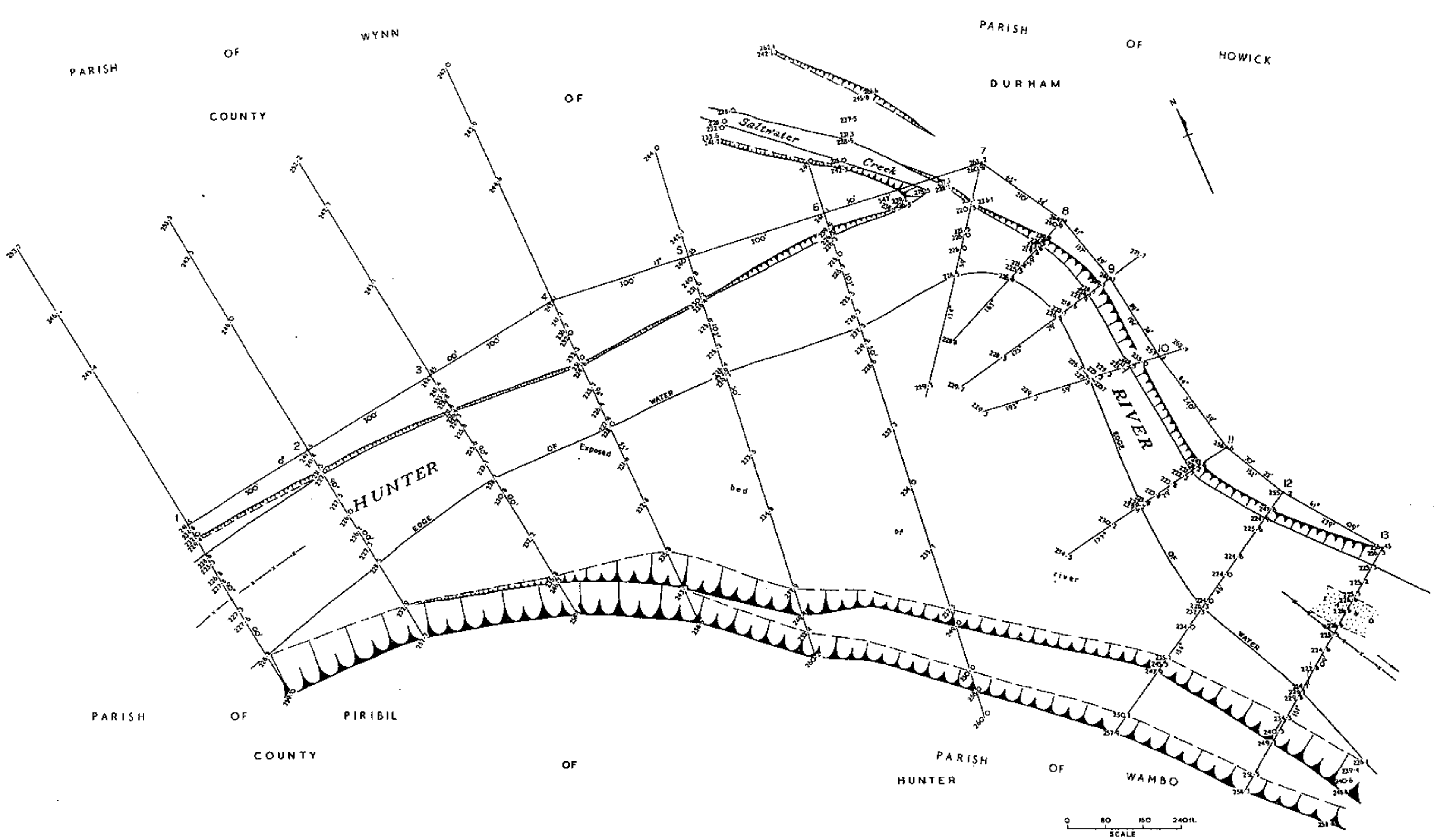


Figure 24: Suspended sediment size grading.

CE-E-7319



LIDDELL POWER STATION

FIGURE 25: PROPOSED PUMPING STATION SITE AT JERRY'S PLAINS

1964 SURVEY CORRECT - JULY 1965

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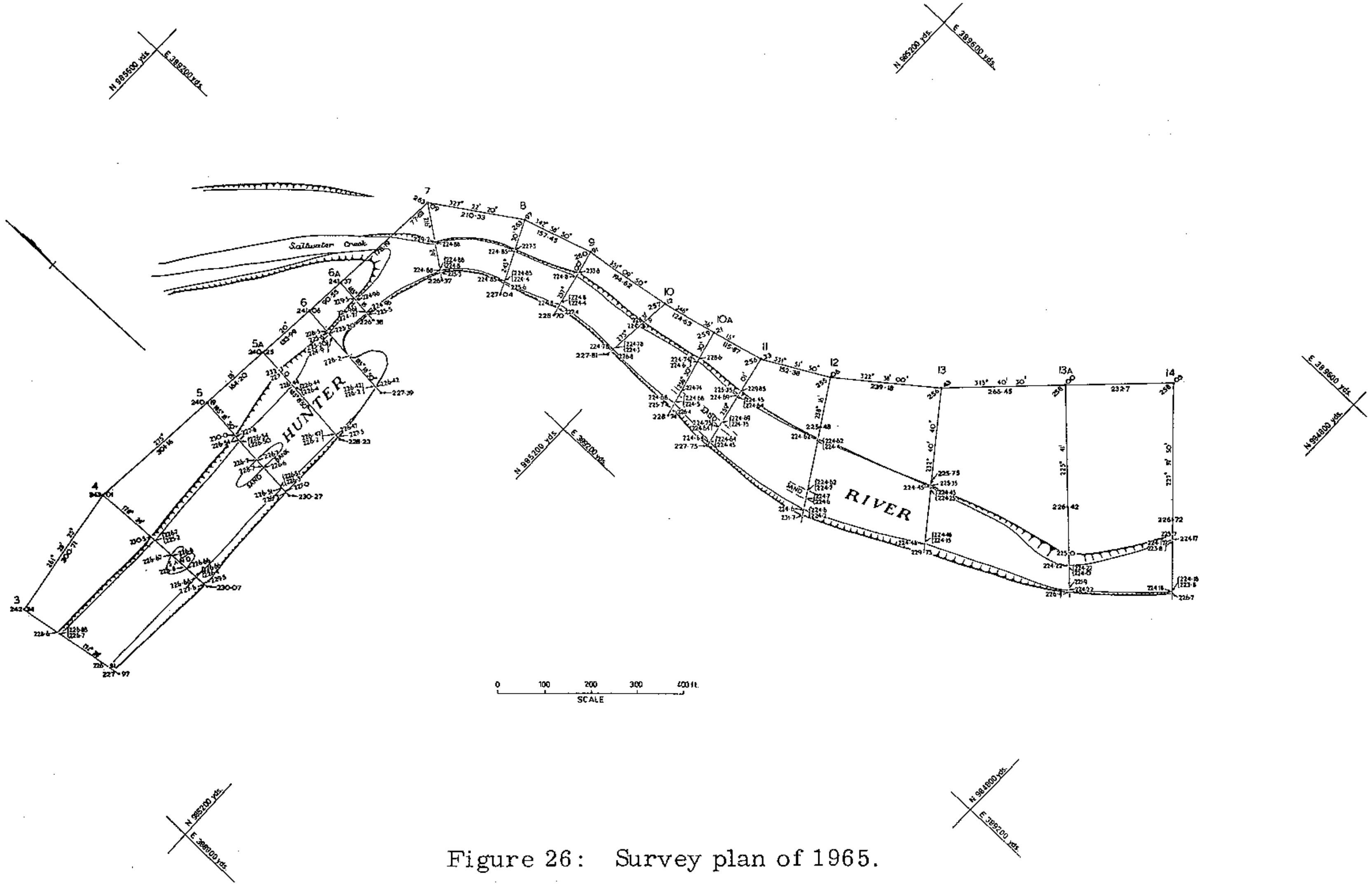

Figure 26: Survey plan of 1965.

CE - B - 6463

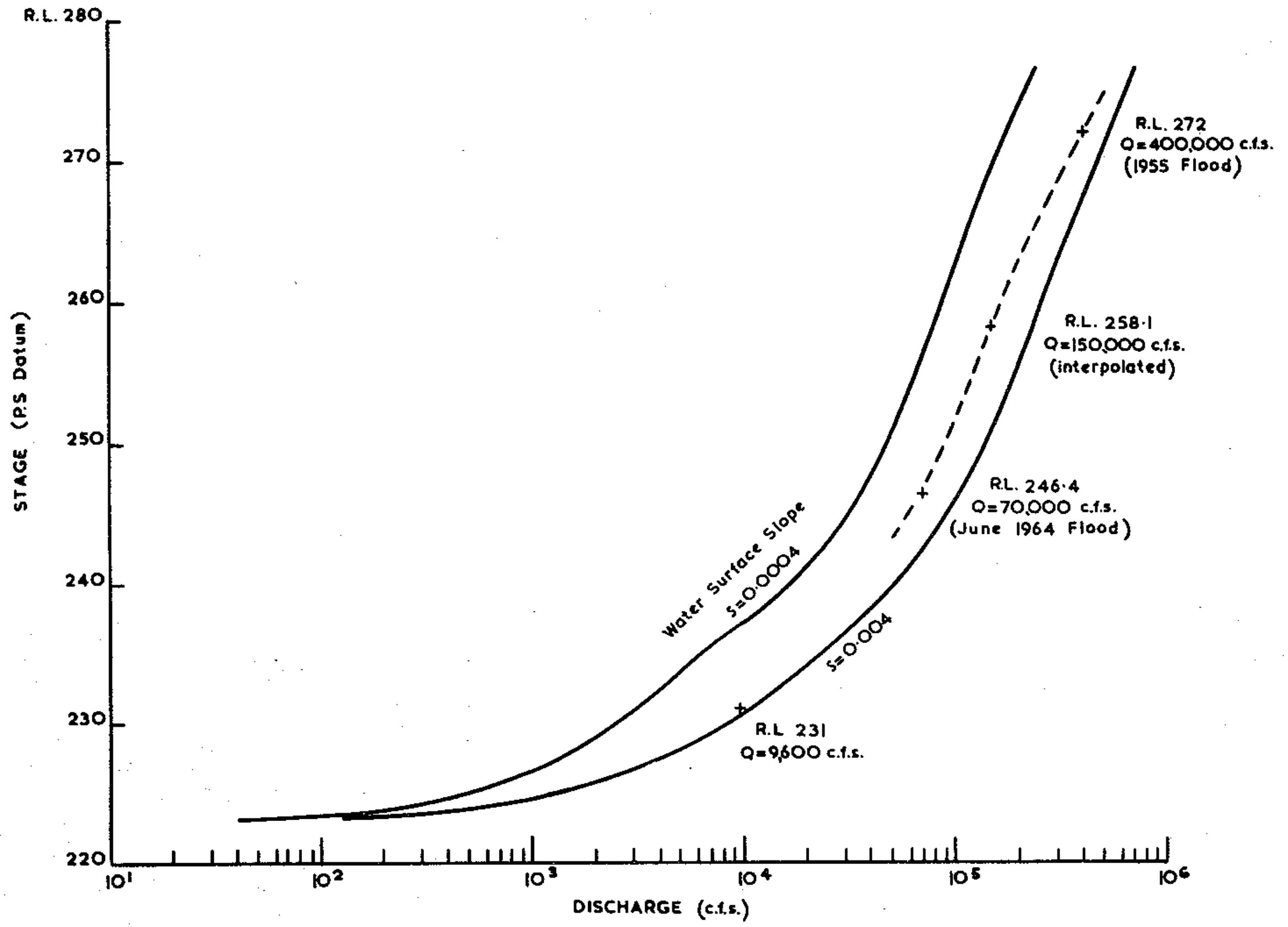

Figure 27: Synthetic stage-discharge curve, Survey Section 11 - Slope Area Method.

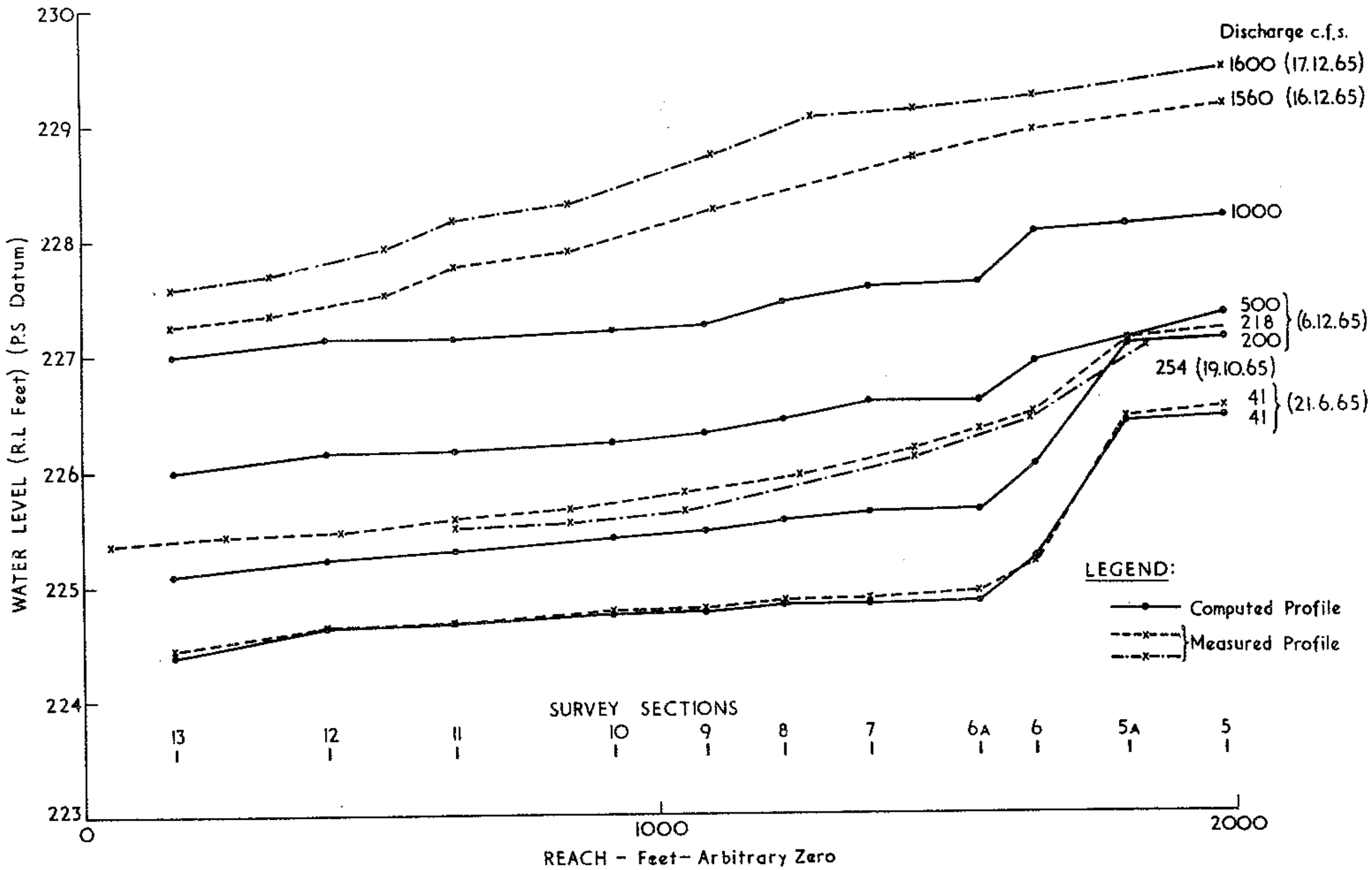

Figure 28: Computed and measured river surface profile (low flow).

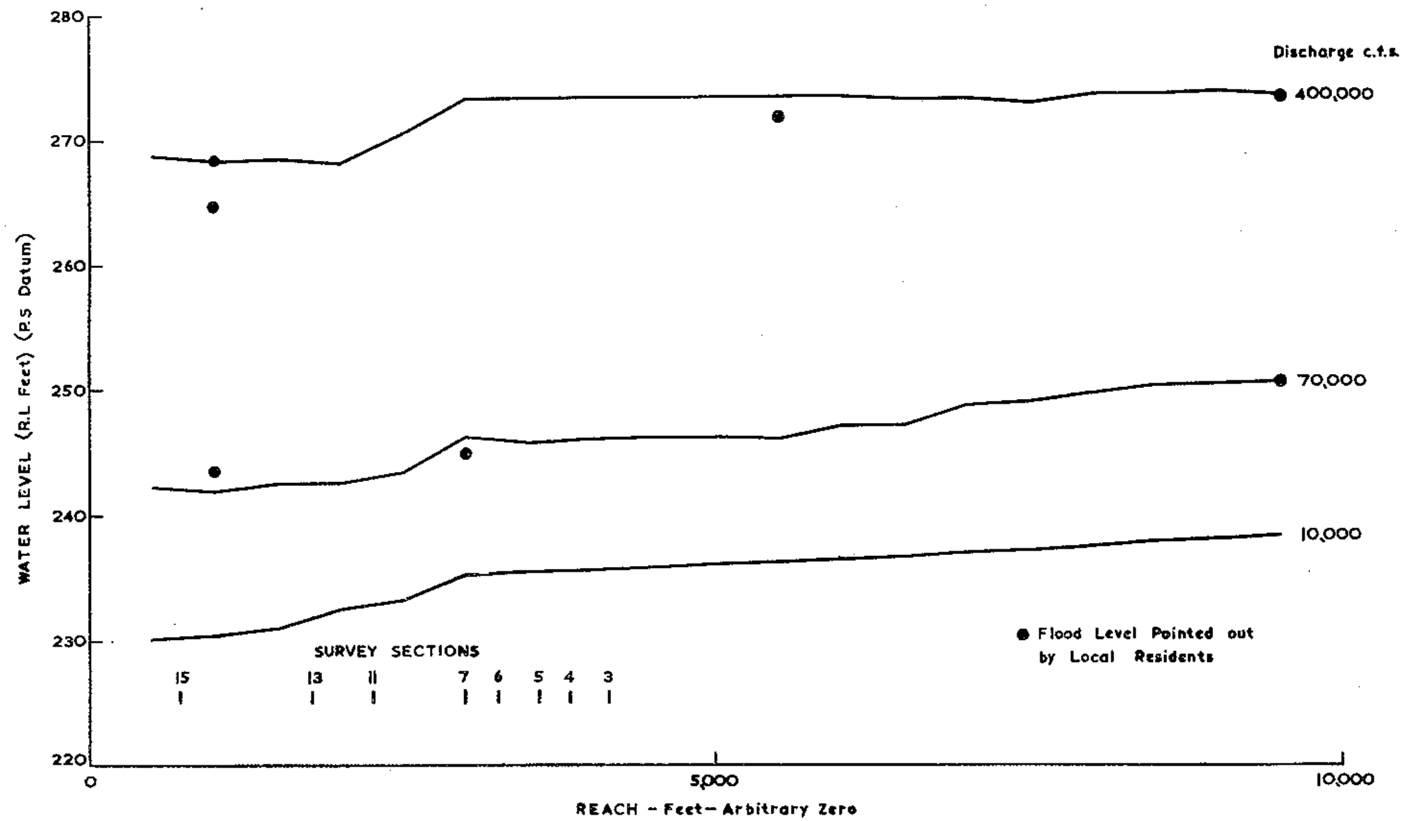

Figure 29: Computed river surface profile (high flow).

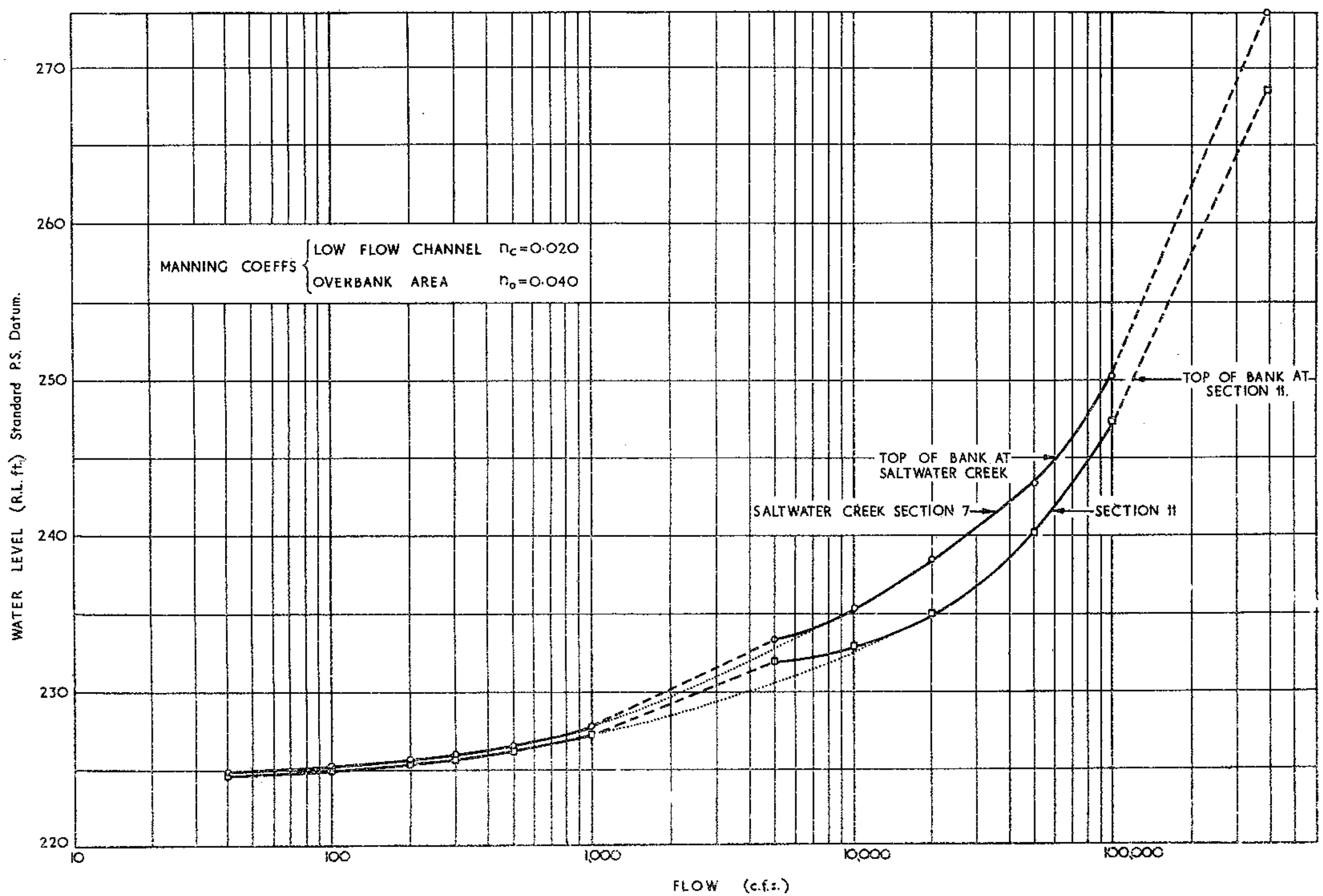

Figure 30: Synthetic stage-discharge curve.
Survey Section 11 - backwater analysis.