PROGRESS REPORT, 1500 FT.
CONTRACTION PLAN
MIDDLE MISSISSIPPI RIVER
MILE 168 TO 154

SLD POTAMOLOGY STUDY (S-4)
VOLUME I
RIVER STABILIZATION BRANCH

U. S. ARMY ENGINEER DISTRICT, ST. LOUIS
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI

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FOREWARD

This study was prepared by Mr. Claude N. Strauser, Potamologist, and Mr. Gary W. Schwartz, Assistant Potamologist, River Stabilization Branch.

Special acknowledgements are due the following persons for their assistance and cooperation:

Mr. Lester Arms, Chief, Mapping Section, Survey Branch

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Mr. William Meldrum, Computation Section, Survey Branch

Mrs. J. Bernice Thornton, Survey Branch

Mrs. Lois J. King, Project Planning Branch

This study was prepared under the direction of Mr. Jack R. Niemi, Chief, Engineering Division, and Mr. Norbert C. Long, Chief, River Stabilization Branch.

Colonel Leon E. McKinney, CE, was District Engineer and Major Ronald E. Wernitznig was Deputy District Engineer during the preparation of this study.

Without the cooperation and assistance of all of the above named persons, this study would not have been possible. Their aid was greatly appreciated.

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MIDDLE MISSISSIPPI RIVER

Miles 168.0 to 154.0

I - INTRODUCTION

On 14 April 1975, Mr. Jack R. Niemi, Chief, Engineering Division, appeared before Lower Mississippi Valley Division (LMVD) personnel to acquaint them with some of the problems that the St. Louis District (SLD) was facing.

One of the problems that he discussed was this District's wish to obtain updated surveys in order to evaluate the effectiveness of the different 1500-foot contraction plans that have been constructed in the Middle Mississippi River (miles 195.0 to 0.0).

On 17 June 1975, Mr. R. H. Resta, Chief, Engineering Division, Lower Mississippi Valley Division, gave his written approval to proceed with a potamology study to evaluate the effectiveness of the various 1500-foot contraction plans and submit recommendations on the most efficient plan for use in completing the authorized project.

On 20 May 1975, Mr. Claude N. Strauser, Potamologist, River Stabilization Branch, requested current hydrographic surveys in the reaches containing the various 1500-foot contraction plans. The surveys were obtained during July and August 1975 in order to take advantage of the favorable river stages available at that time.

On 14 November 1976, Mr. Norbert C. Long, Chief, River Stabilization Branch, requested that the reach of river between Mississippi River miles 168.0 to 154.0 be the first area investigated. The other reaches containing 1500-foot contractions would be studied at a later date.

This study will examine the initial 1500-foot contraction plan presently in place between miles 168.0 to 154.0 and will evaluate its effectiveness and make recommendations concerning future design criteria for this area.

II - BACKGROUND INFORMATION

This study will compare data obtained from hydrographic surveys that were made during December 1965, December 1970-January 1971, August 1973 and August 1975.

It has been the opinion of the River Stabilization Branch that an analysis of hydrographic surveys should be associated with the Low Water Reference Plane (LWRP). This theoretical plane is based upon a low flow discharge of 54,000 c.f.s. There are advantages in making comparisons with regard to the LWRP, one of which is the elimination of the problem associated with deposition and the related "masking" of the navigation channel geometry.

It has also been the opinion of the River Stabilization Branch that comparisons among hydrographic surveys should only be made when "similar" stage conditions exist. As stated in Senate Document No. 204, 63d Congress, 1st Session, dated 15 May 1913:

> ". . . the only way to determine whether the river bed is rising or being scoured out, is by comparing corresponding low waters with each other, or corresponding high waters."

Since the surveys shown in Table No. 1 are all essentially similar in stage, comparisons made in this study should be valid. The maximum stage fluctuation on the Middle Mississippi River is approximately 50.0 feet (-6.2 feet, 16 January 1940, to 43.3 feet, 28 April 1973, at St. Louis), whereas the average stage fluctuation for the surveys used in this study is only 5.0 feet.

TABLE NO. 1

LISTING OF HYDROGRAPHIC SURVEYS USED IN THIS STUDY

Date	Average Stage Above LWRP*	Average Water Temp. °F	Mileage Covered
1965 December	8.0	43	154.00 - 167.25
1970-1971 December-January	6.2	35	154.00 - 168.55
1973 August	11.2	78	154.00 - 168.55
1975 August	7.6	78	154.00 - 168.56

*Note: Similar stages are not always accompanied by similar discharges.

The 1500-foot contraction plan for this reach of river was not constructed as shown on the Master Plan for the 9-foot navigation project. As in most of the activities on the Middle Mississippi River, a rather conservative approach has been adopted as an overall policy. It has been the policy to build the 1500-foot contraction plan in phases and examine the river's response after each phase of construction activity. This is not a new policy but, rather, the continuation of a policy established by Colonel J. H. Simpson in 1875:

> "Nature overlooks nothing, and we may confidently assume that the position and direction of the river, at any time, is the resultant of all forces, and consequently, is a concrete expression of the law of the stream, which we may modify and preserve, but may not safely destroy or radically change."

This gradual approach to obtain project objectives is also the most economical. If the regulating structures are properly designed, the natural laws of the river can be made to accomplish much of the desired work. This again is not a new idea.

". . . the potent forces, judiciously handled, can be made to do no inconsiderable part of the work." (Simpson, 1875)

Each phase of construction activity must serve two purposes:

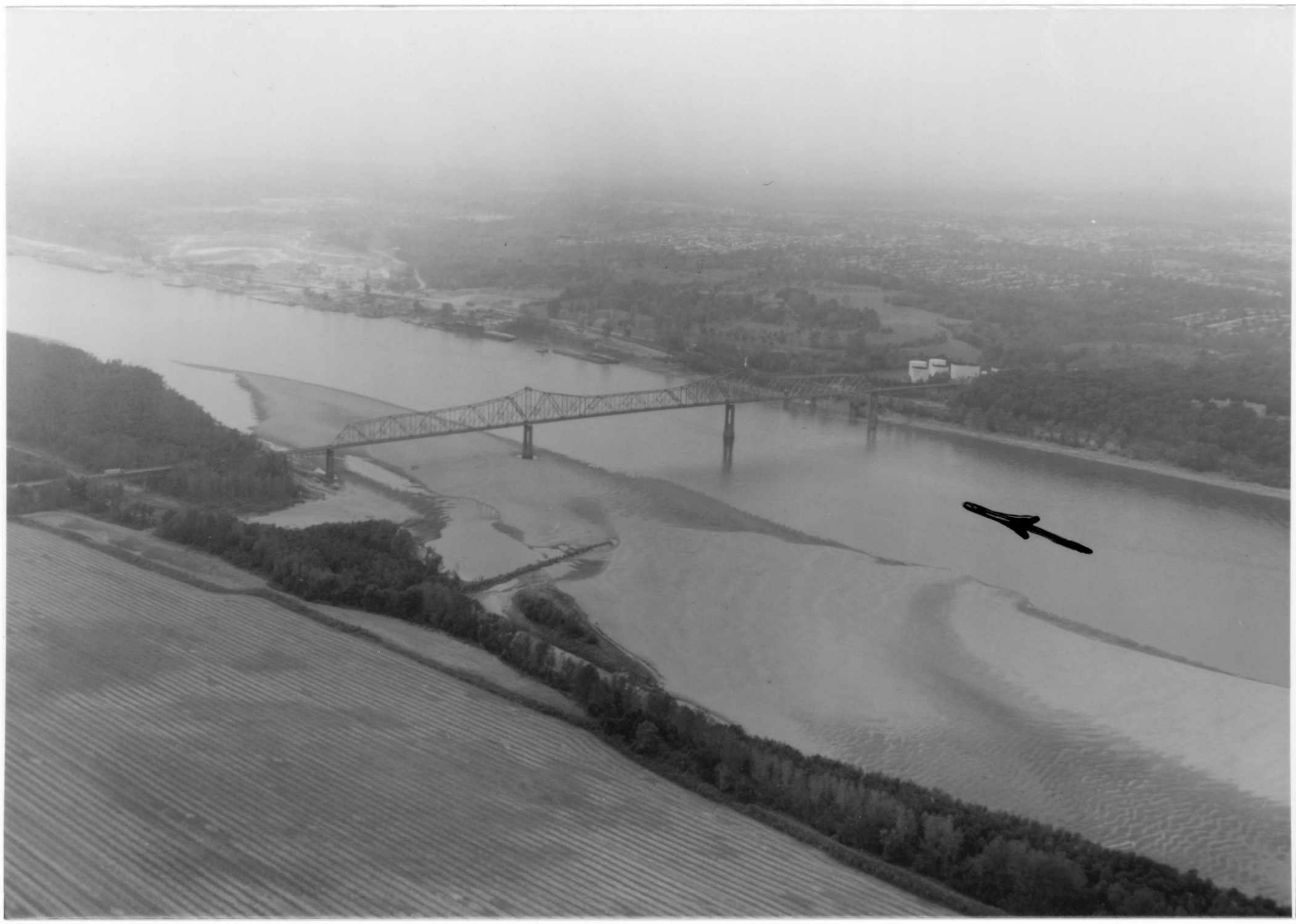
1. Solve immediate problems and needs.

2. Contribute to the overall accomplishment of the Master Plan for obtaining and maintaining a dependable navigation system.

The progress towards this goal has required the efforts of many generations of highly skilled and knowledgeable river engineers and the completion of these works may require several more generations of dedicated men. Each generation of river engineers realizes that ". . . it is entirely practicable to make every step in the interests of immediate wants a step, also, toward the final end, without adding to the cost or delaying the realization of the benefit desired." (Simpson, 1875)

In order to place the channel geometry in perspective, each mile must be examined with respect to time and also with respect to contractive effort, dike spacing, dike height and physical condition of each dike (stone, pile, etc.). This was accomplished by the use of hydrographic survey sheets and aerial photographs that were time oriented. In conjunction with the aforementioned data, transparent overlays containing plots of various geometric parameters were also obtained. Coordinating this information and changing the overlays with respect to time helped in evaluating the observed river responses.

With the above background information in mind, an examination of the first phase of construction that was designed to eventually achieve a 1500-foot contraction in this reach will be examined.



SEPTEMBER 1976   ST. LOUIS GAGE 1.5

Looking downstream towards the Jefferson Barracks Highway Bridge (MRM 168.7). An old pile dike (168.8 L) is in the foreground amongst a huge sandbar.

III - PRESENTATION OF DATA

A. Average Navigation Channel Width.

To determine the change in navigation width, it is first necessary to define this term. Navigation width will be used in this study as the distance between the contour lines on the hydrographic surveys that are located 10 feet below the LWRP (project depth is 9 feet below the LWRP, however the -10-foot contour was chosen for convenience).

In order to compare changes in the average navigation channel widths that were brought about by changing the contraction to present conditions, comparisons among the different hydrographic surveys were made. The results of these comparisons are summarized in Table No. 2.

TABLE NO. 2

AVERAGE NAVIGATION WIDTHS	
1965	1050 ft.
1970-1971	1005 ft.
1973	995 ft.
1975	810 ft.

The width of the navigation channel decreased by 240 feet from 1965 to 1975. Of this 240-foot decrease, 185 feet occurred between 1973 and 1975 (77%).

The following computer generated plots make various time related comparisons and graphically reveal the changes in average navigation widths that this reach of river has experienced. See Appendix A.

Plate No.	Description
1	December 1965/December 1970-January 1971
2	December 1970-January 1971/August 1973
3	August 1973/August 1975
4	December 1965/August 1975
5	Width at 10' Below LWRP/Stage Above LWRP

B. Average Depth Below the LWRP.

A comparison of the average navigation depth below the LWRP is summarized in Table No. 3.

As can be seen, the navigation depths have been steadily decreasing since 1965 and the initial Phase I construction activites have not reversed the trend. The loss of approximately 2 feet in average depth between 1965 and 1975 needs further examination. Of this 2-foot decrease, 1.2 feet occured between 1973 and 1975 (60%).

TABLE NO. 3

AVERAGE DEPTH BELOW THE LWRP	
1965	12.1 ft.
1970-1971	11.6 ft.
1973	11.3 ft.
1975	10.1 ft.

To graphically examine these changes, computer generated plots of the average depth below the LWRP vs. river mile were created. The comparisons were made in relation to time. See Appendix A.

Plate No.	Description
6	December 1965/December 1970-January 1971
7	December 1970-January 1971/August 1973
8	August 1973/August 1975
9	December 1965/August 1975
10	Average Depth Below LWRP/Stage Above LWRP

C. Average Area Below the LWRP.

As can be expected, similar results should be obtained when you combine width and depth and investigate the area below the LWRP.

TABLE NO. 4

AVERAGE AREA BELOW THE LWRP	
1965	20,800 sq. ft.
1970-1971	19,325 sq. ft.
1973	19,480 sq. ft.
1975	17,200 sq. ft.

The average area below the LWRP decreased by 3,600 square feet between 1965 and 1975. Of this amount, 2,280 square feet occurred between 1973 and 1975 (63%).

The following computer generated plots graphically display the changes with respect to time. See Appendix A.

Plate No.	Description
11	December 1965/December 1970-January 1971
12	December 1970-January 1971/August 1973
13	August 1973/August 1975
14	December 1965/August 1975
15	Area Below LWRP/Stage Above LWRP

D. Width/Depth Ratio Below the LWRP.

TABLE NO. 5

WIDTH/DEPTH RATIO BELOW THE LWRP	
1965	163
1970-1971	154
1973	165
1975	180

The width/depth ratio below the LWRP increased by 17 between 1965 and 1975. Of this amount, 15 occurred between 1973 and 1975 (88%).

The following computer generated plots graphically display the changes with respect to time. See Appendix A.

Plate No.	Description
16	December 1965/December 1970-January 1971
17	December 1970-January 1971/August 1973
18	August 1973/August 1975
19	December 1965/August 1975
20	Width-Depth Ratio/Stage Above LWRP

E. Width at the LWRP.

TABLE NO. 6

WIDTH AT LWRP

1965	1782
1970-1971	1700
1973	1753
1975	1727

The average width of the navigation channel at the LWRP has remained relatively constant from 1965 to 1975. There has been no significant change.

F. Comparisons of Total Channel Geometry.

In addition to the investigations associated with the LWRP, investigations were made with reference to the total geometry present at the time the hydrographic surveys were obtained. As a result, the following computer generated plots were created. See Appendix A.

Plate No.	Description
21	Total Width/Depth Ratio/Stage Above LWRP
22	Total Area/Stage Above LWRP
23	Total Area/Area Below LWRP

G. Supplementary Data.

The section factor ($AR^{2/3}$), Manning's "N" and the hydraulic depth were also investigated and the following computer generated plots were obtained. See Appendix A.

Plate No.	Description
24	Section Factor/Stage Above LWRP
25	Stage Above LWRP/Manning's "N"
26	Hydraulic Depth/Manning's "N"

IV - ANALYSIS

The analysis of this reach of river was complicated and required many hours of investigation and discussion. Information available from sources not presented in this study and the experiences of senior river engineers were necessary to obtain an understanding of the channel mechanisms that were peculiar to this area. A time oriented approach to understanding the data presented in this study was beneficial. Other approaches proved less revealing and in some instances were misleading.

The first fact that became apparent after reviewing the data previously presented in this study was the importance of the events centering around the year 1973.

In 1973, the Middle Mississippi River experienced a record breaking flood. Large quantities of material were deposited in the river above this study reach. Of even more importance is the fact that the reach of river immediately above (mile 182 to mile 168) has not had any river regulating works constructed or maintained since 1948 (approximately 30 years). This reach has been steadily deteriorating and channel efficiency has has been "declining." This lack of maintenance to river regulating structures and resulting bankline deterioration have contributed to an increased amount of dredging activity required to keep this reach navigable. See picture page 6.

The reach of river (mile 182 to mile 168) immediately above this study reach (mile 168 to mile 154) received substantial amounts of deposition during the flood of 1973. This reach (mile 182 to mile 168) was so inefficient that the deposited material was not effectively conveyed to the study reach (mile 168 to mile 154) until much later. Perhaps the high water experienced in the spring of 1974 also had a significant effect on the study reach. Eventually, however, the material that was deposited during the high water began to work its way downstream and began to show up in the August 1975 surveys.

The second fact that appeared to be important was the construction sequence of the first phase of the 1500-foot contraction plan between miles 168.0 to 154.0.

It has been the policy of the River Stabilization Branch, Engineering Division, to construct regulating works in an upstream to downstream sequence, whenever possible. Construction of the first phase of the 1500-foot contraction began at mile 140.0 (immediately below the 1200-foot contraction study reach) and progressed downstream in segments.

The reach between miles 168 and 154 was constructed out of sequence with respect to the overall plan of operation. The unusual construction sequence has probably had a significant effect on the river's response to the first phase of the 1500-foot contraction plan and, as a result, the desirable progression of river development and improved channel geometry has not been achieved in the reach between miles 168 and 154.

The third significant fact that appeared to be relevant was the design of the first phase of the 1500-foot contraction plan. The designer realized that his first priority would be to solve immediate problems and secondly to contribute to the overall plan of operation.

As a result, not all of the contractive effort which was planned was built in this initial phase of construction. A close inspection of this reach shows an inconsistent and segmented contraction line. Some areas still retain the original 1800-foot contraction (see Plates 27, 28 and 29). See Appendix A.

Another result of this initial phase of construction was uneven spacing between the dikes. This was partially caused by imposed physical constraints such as dock facilities, launching ramps, submerged cables, pipeline crossings, etc. Also, several dikes were deleted in order to comply with requests from various federal and state conservation interests who were concerned about the riverine environment in adjacent side channels and backwater areas. As can be expected, this has resulted in areas where excessive dike spacing is apparent.

To reiterate, the initial phase of construction resulted in an inconsistent contractive effort and uneven dike spacing. This, undoubtedly, has influenced the river's response as has been previously discussed.

Another interesting fact that was observed from studying the data developed for this report centers around the low water reference plane (LWRP).

Nearly every investigation conducted with respect to channel geometry below the LWRP indicated deteriorating conditions. Channel geometry at the LWRP showed no significant change and, finally, investigations made with respect to the total geometry showed expected and acceptable results.

This strengthens the belief in the comment stated previously concerning the slow moving passage of depositional material derived from previous high water periods.

V. SUMMARY

The overall condition of this reach of river has been reacting favorably to the recent construction of regulating works as can be seen by reviewing the graphs of:

1. Total Width/Depth Ratio vs. Stage Above LWRP (Plate 21)

2. Total Area vs. Stage Above LWRP (Plate 22)

3. Section Factor vs. Stage Above LWRP (Plate 24)

A review of the following tables which pertain to conditions below the LWRP graphically show channel deterioration.

Table 2 - Average Navigation Width

Table 3 - Average Depth Below the LWRP

Table 4 - Average Area Below the LWRP

Table 5 - Width/Depth Ratio Below the LWRP

September 1976 (St. Louis Gage 1.5)

Looking upstream at approximately MRM 165.

VI - CONCLUSIONS AND RECOMMENDATIONS

1. It is difficult to study a single reach of river without considering data from the reach immediately upstream and the reach immediately downstream. This study had an insufficient amount of data available from the reach immediately above (lower part of the St. Louis Harbor). This lack of data introduced several unknowns that created difficulty in the analysis.

2. Proper construction sequencing should be followed whenever possible. The river's response observed in this study reach did not occur as desired. Other reaches built with similar design criteria and constructed in an upstream to downstream order responded favorably.

3. The effect of upstream deterioration and resulting loss of channel efficiency needs to be more fully investigated. Factors such as caving banks, land fills, harbor-port developments, dredging activities, etc., need to be considered. Up-to-date hydrographic surveys are mandatory to achieve this important objective.

4. The major flood of 1973 and the high water periods subsequent to that time require further investigation. An investigation of the loop effect of the 1973 stage-discharge curve at St. Louis may reveal some valuable information in regard to depositional processes that may have had a significant effect on the downstream channel deterioration that this study observed.

5. It is recommended that Phase II construction activities in this study reach be designed to provide consistent dike spacing and contractive effort, whenever possible.

6. Other 1500-foot contraction plans that are located between mile 140 to mile 107 should be investigated to evaluate their effectiveness before final conclusions and recommendations are established.

7. Consideration should be given to initiating activities that would result in stabilization of the reach of river between mile 182 and mile 168. Lack of maintenance on existing structures has most probably been a cause of channel deterioration.

APPENDIX A

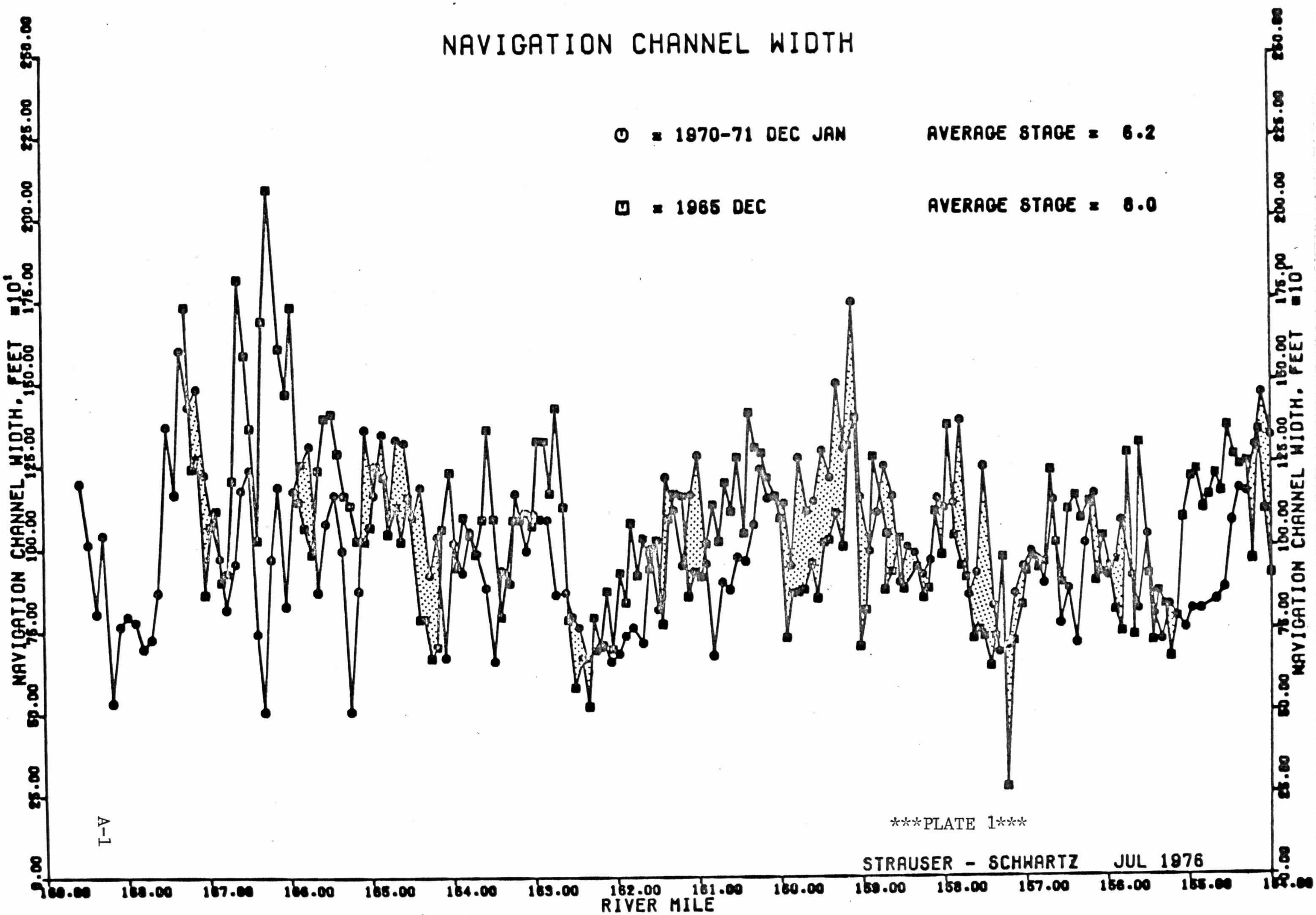
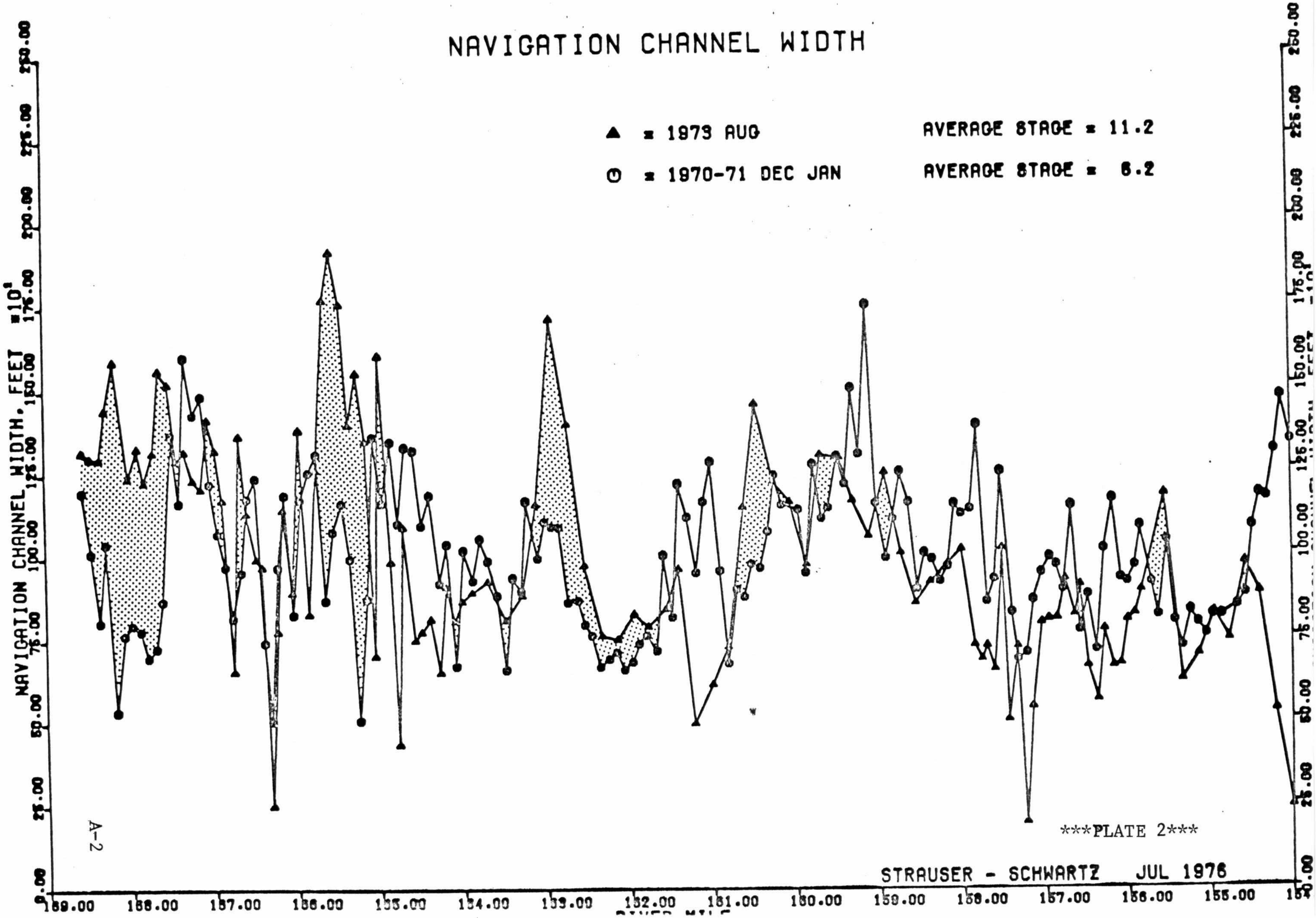

NAVIGATION CHANNEL WIDTH
⊙ = 1970-71 DEC JAN
AVERAGE STAGE = 6.2
⊡ = 1965 DEC
AVERAGE STAGE = 8.0
NAVIGATION CHANNEL WIDTH, FEET ×10¹
RIVER MILE
STRAUSER - SCHWARTZ JUL 1976

PLATE 1


NAVIGATION CHANNEL WIDTH
▲ = 1973 AUG
⊙ = 1970-71 DEC JAN
AVERAGE STAGE = 11.2
AVERAGE STAGE = 6.2
NAVIGATION CHANNEL WIDTH, FEET *10¹
0.00
25.00
50.00
75.00
100.00
125.00
150.00
175.00
200.00
225.00
250.00
169.00
168.00
167.00
166.00
165.00
164.00
163.00
162.00
161.00
160.00
159.00
158.00
157.00
156.00
155.00
154
STRAUSER - SCHWARTZ JUL 1976
PLATE 2

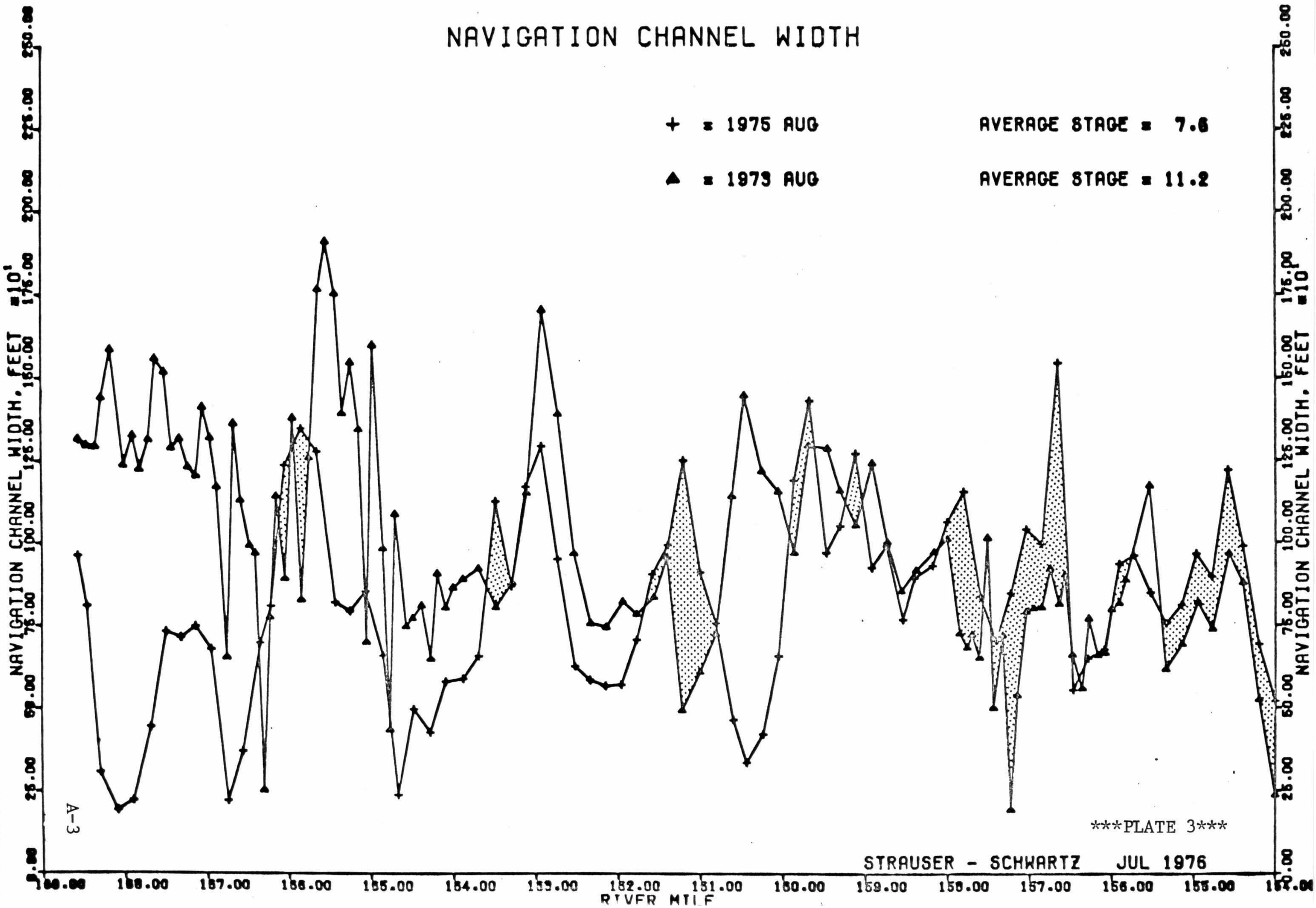
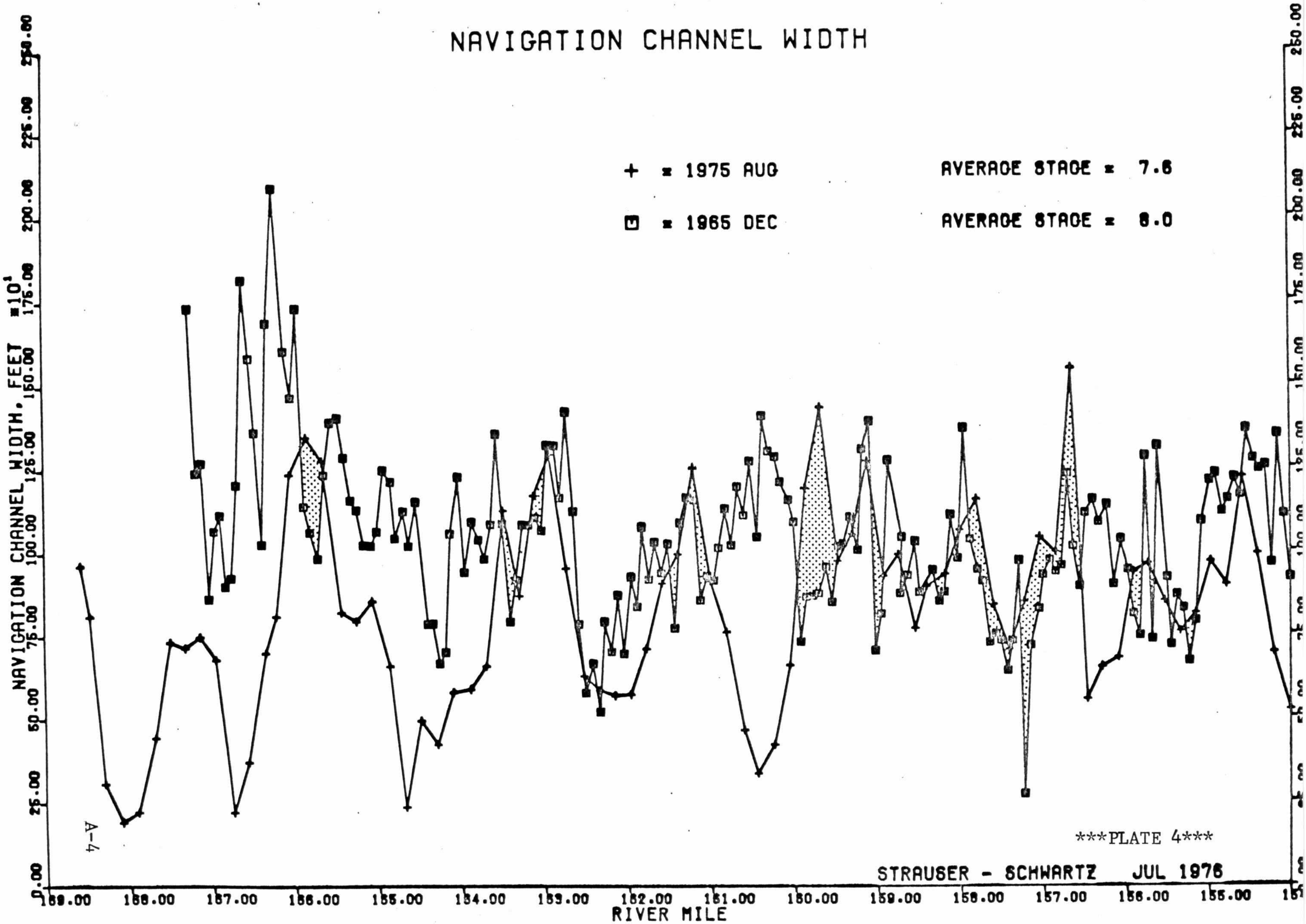
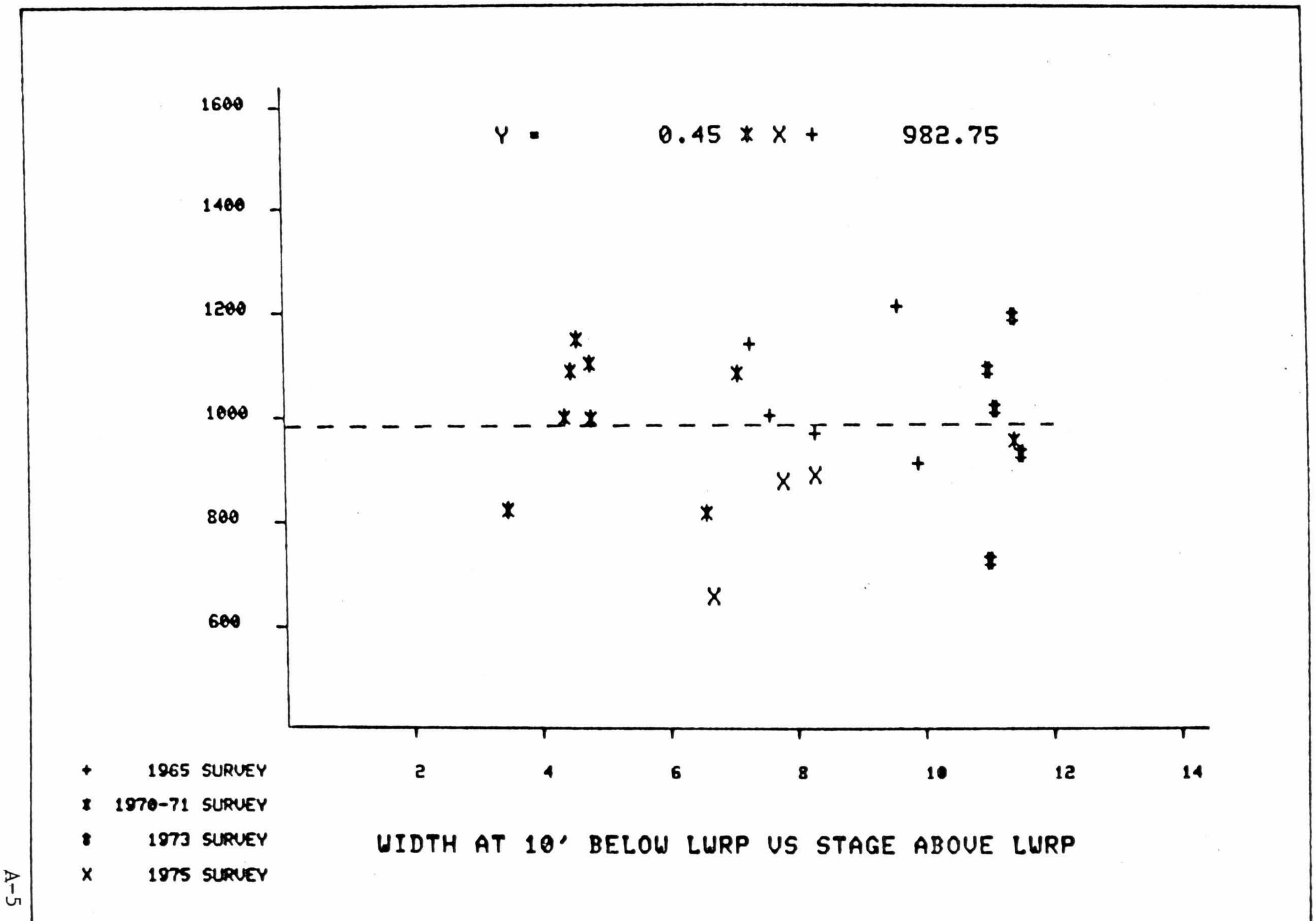

NAVIGATION CHANNEL WIDTH
+ = 1975 AUG
▲ = 1973 AUG
AVERAGE STAGE = 7.6
AVERAGE STAGE = 11.2
NAVIGATION CHANNEL WIDTH, FEET ×10¹
RIVER MILE
STRAUSER - SCHWARTZ JUL 1976

PLATE 3



NAVIGATION CHANNEL WIDTH
+ = 1975 AUG
AVERAGE STAGE = 7.6
= 1965 DEC
AVERAGE STAGE = 8.0
NAVIGATION CHANNEL WIDTH, FEET ×10¹
RIVER MILE
STRAUSER - SCHWARTZ JUL 1976

PLATE 4



Y = 0.45 * X + 982.75
1600
1400
1200
1000
800
600
2
4
6
8
10
12
14
+ 1965 SURVEY
* 1970-71 SURVEY
* 1973 SURVEY
X 1975 SURVEY
WIDTH AT 10' BELOW LWRP VS STAGE ABOVE LWRP

PLATE 5

AVERAGE DEPTH BELOW LOW WATER REFERENCE PLANE

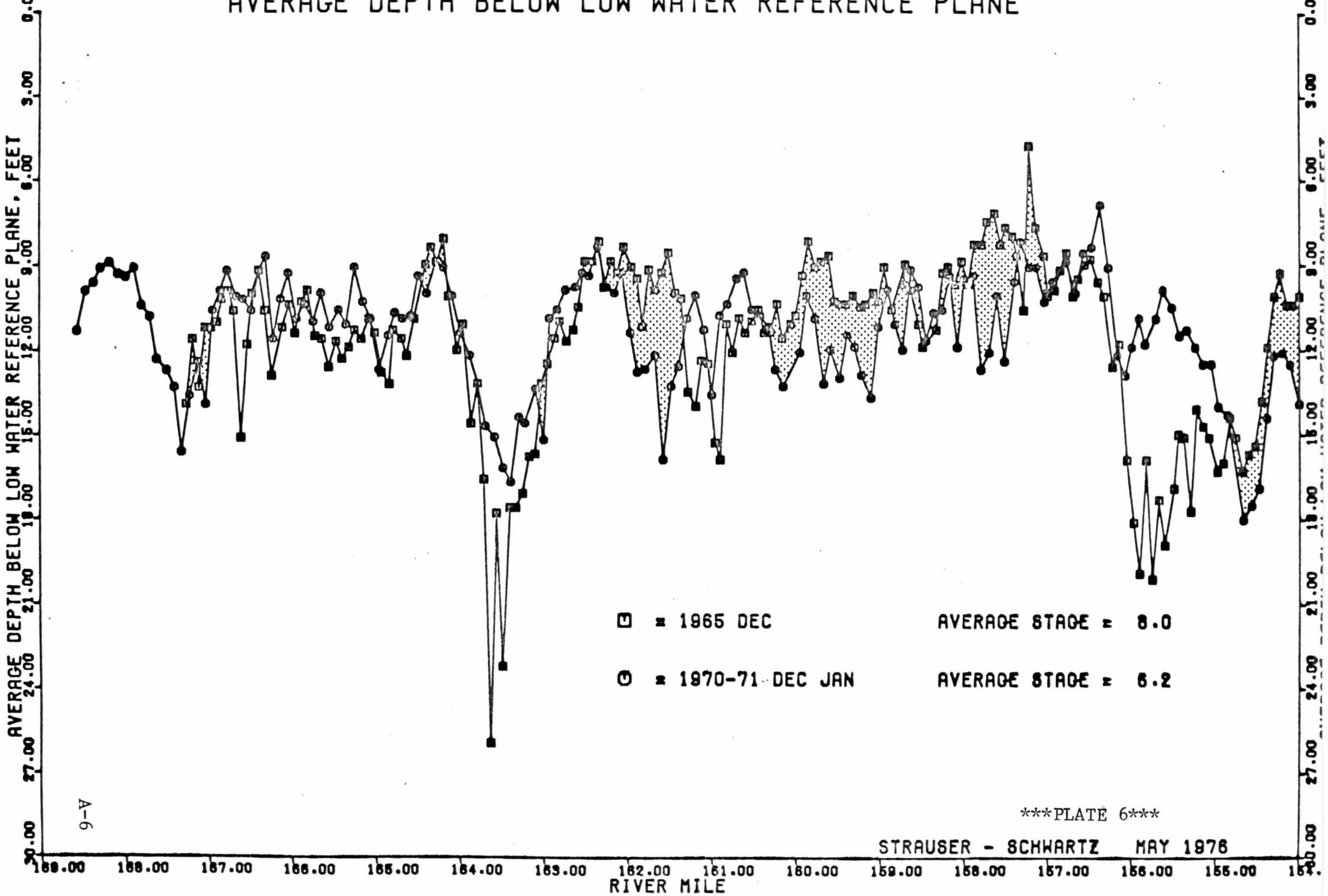


PLATE 6

STRAUSER - SCHWARTZ MAY 1976

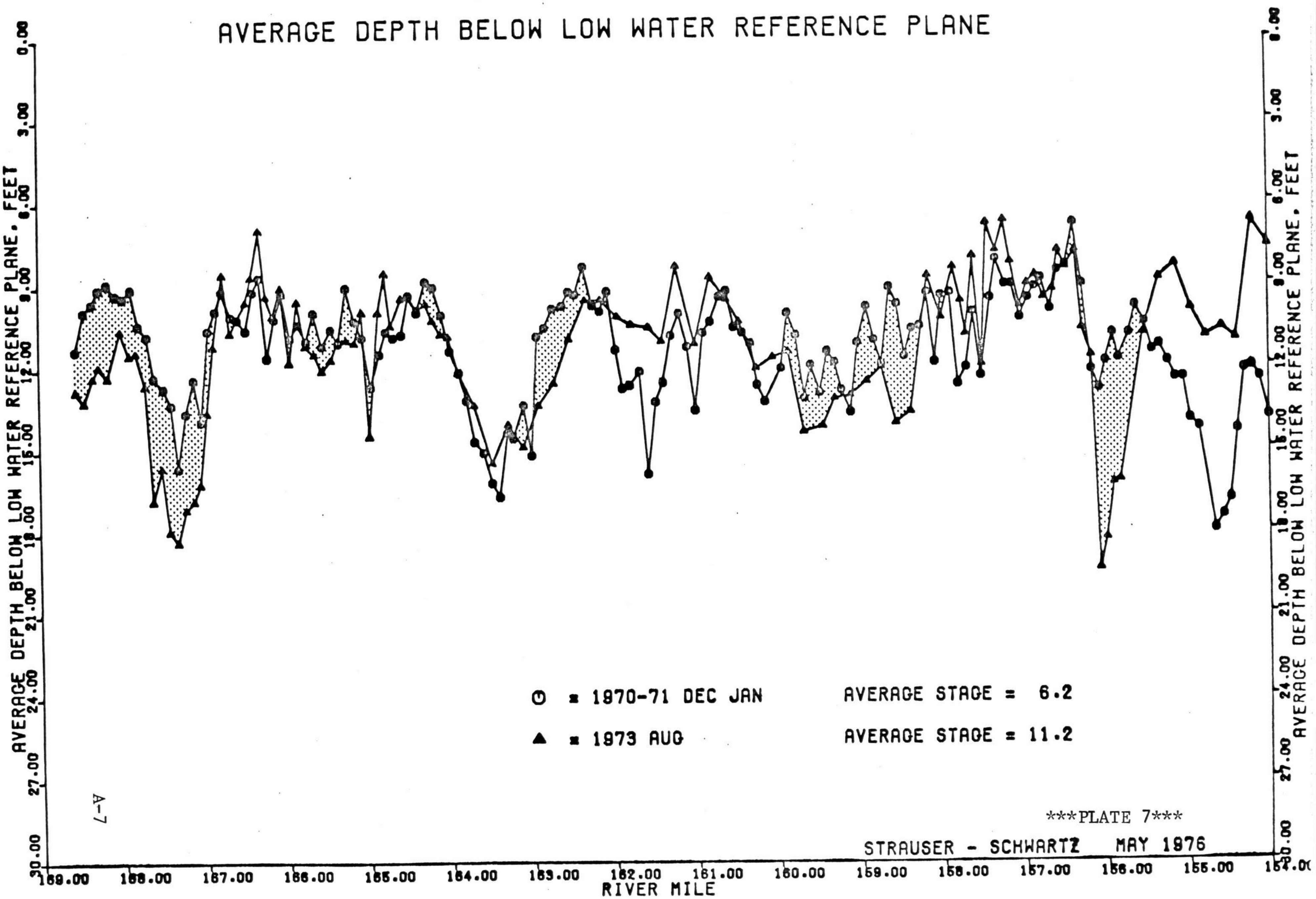


PLATE 7

STRAUSER - SCHWARTZ MAY 1976

AVERAGE DEPTH BELOW LOW WATER REFERENCE PLANE

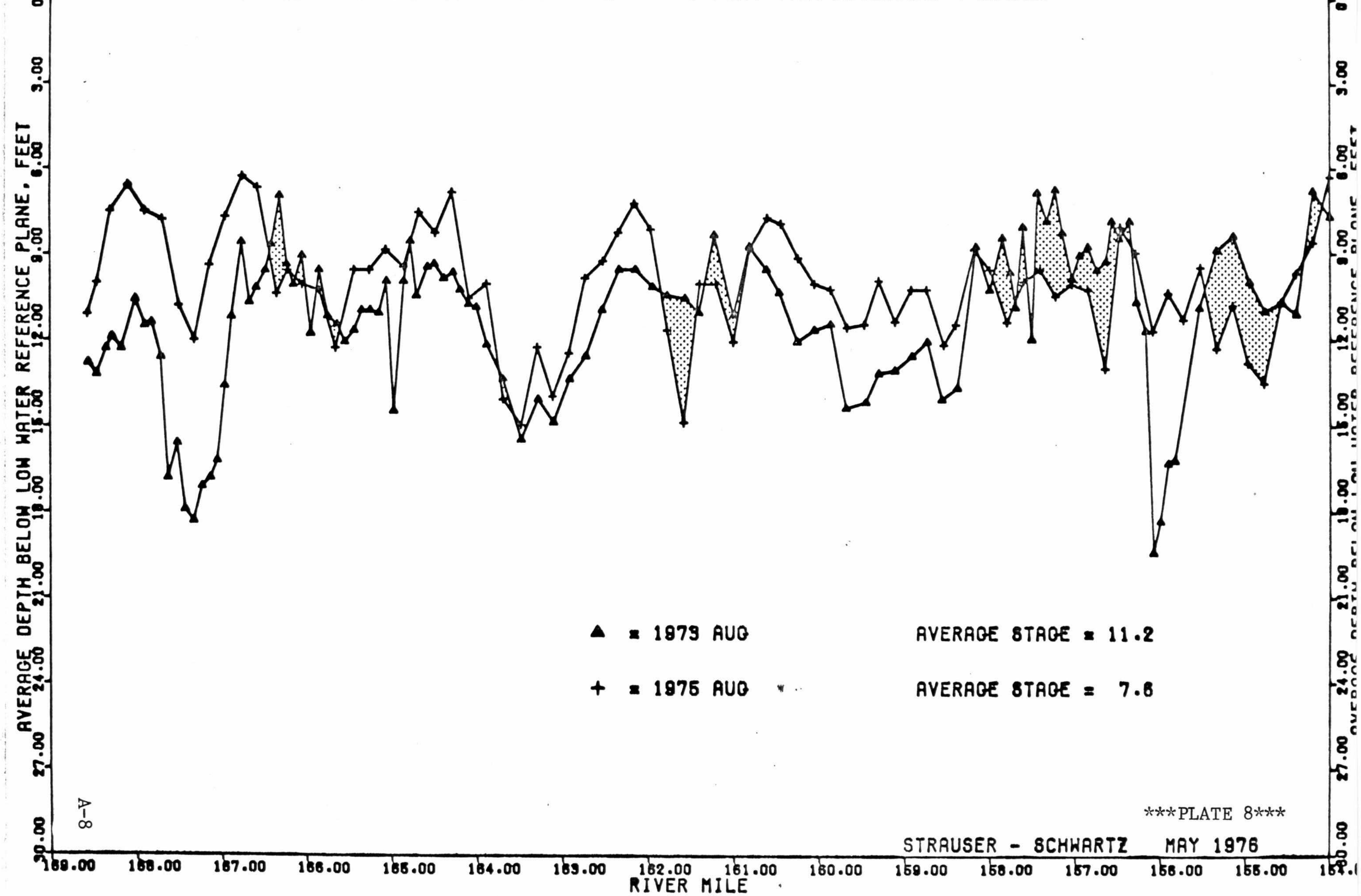
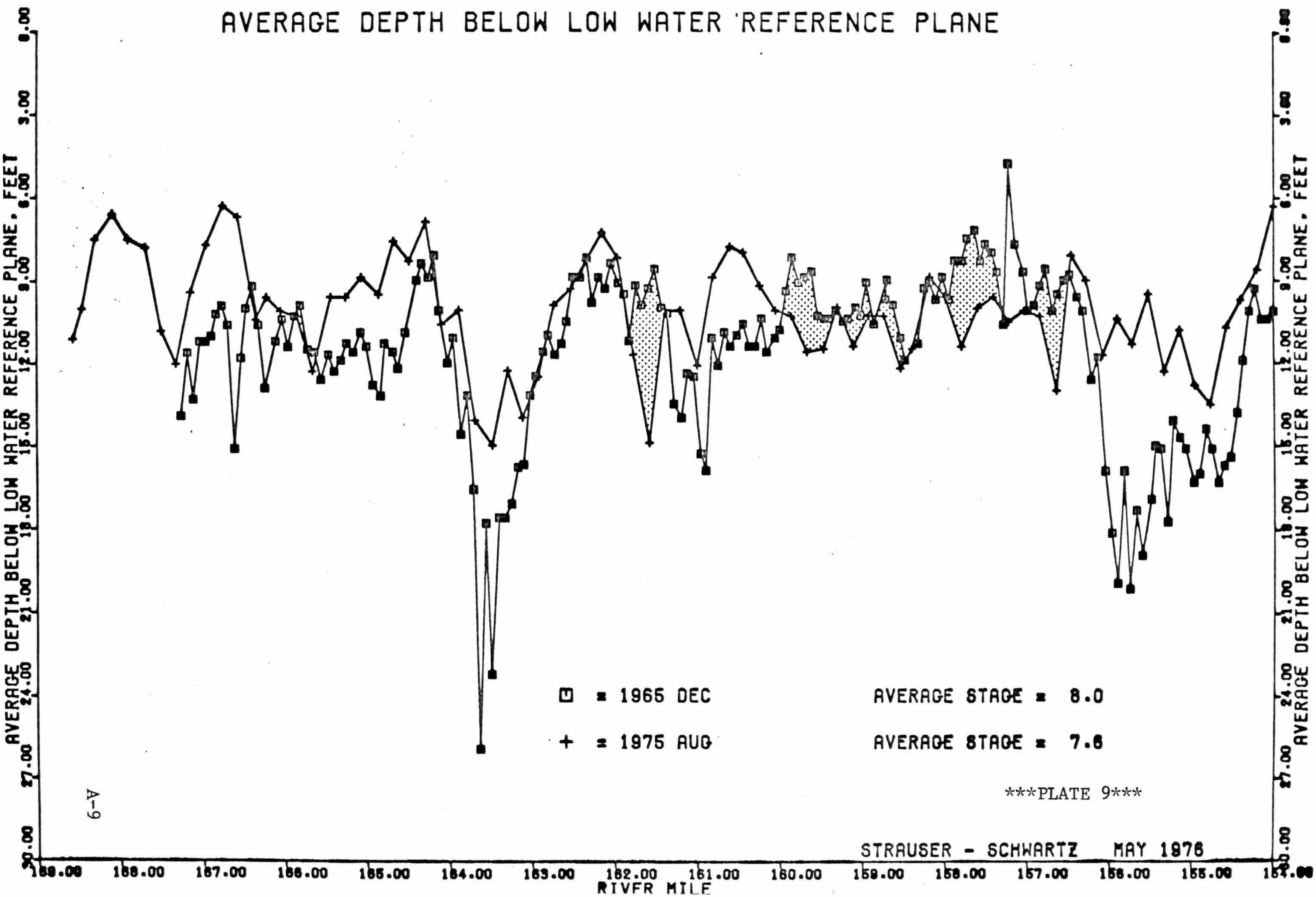


PLATE 8

STRAUSER - SCHWARTZ MAY 1976



AVERAGE DEPTH BELOW LOW WATER REFERENCE PLANE
AVERAGE DEPTH BELOW LOW WATER REFERENCE PLANE, FEET
RIVER MILE
= 1965 DEC
+ = 1975 AUG
AVERAGE STAGE = 8.0
AVERAGE STAGE = 7.6
STRAUSER - SCHWARTZ MAY 1976

PLATE 9

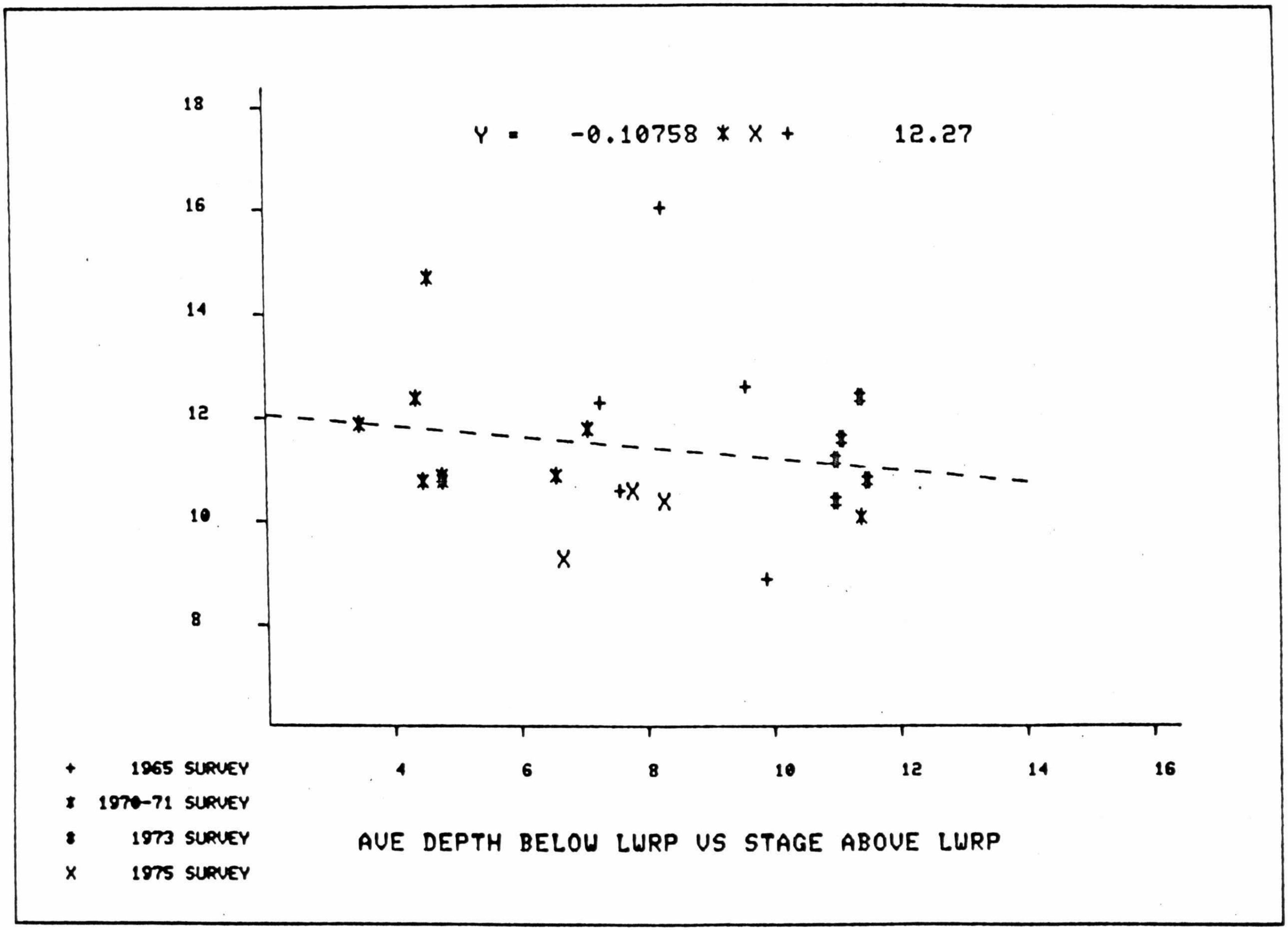
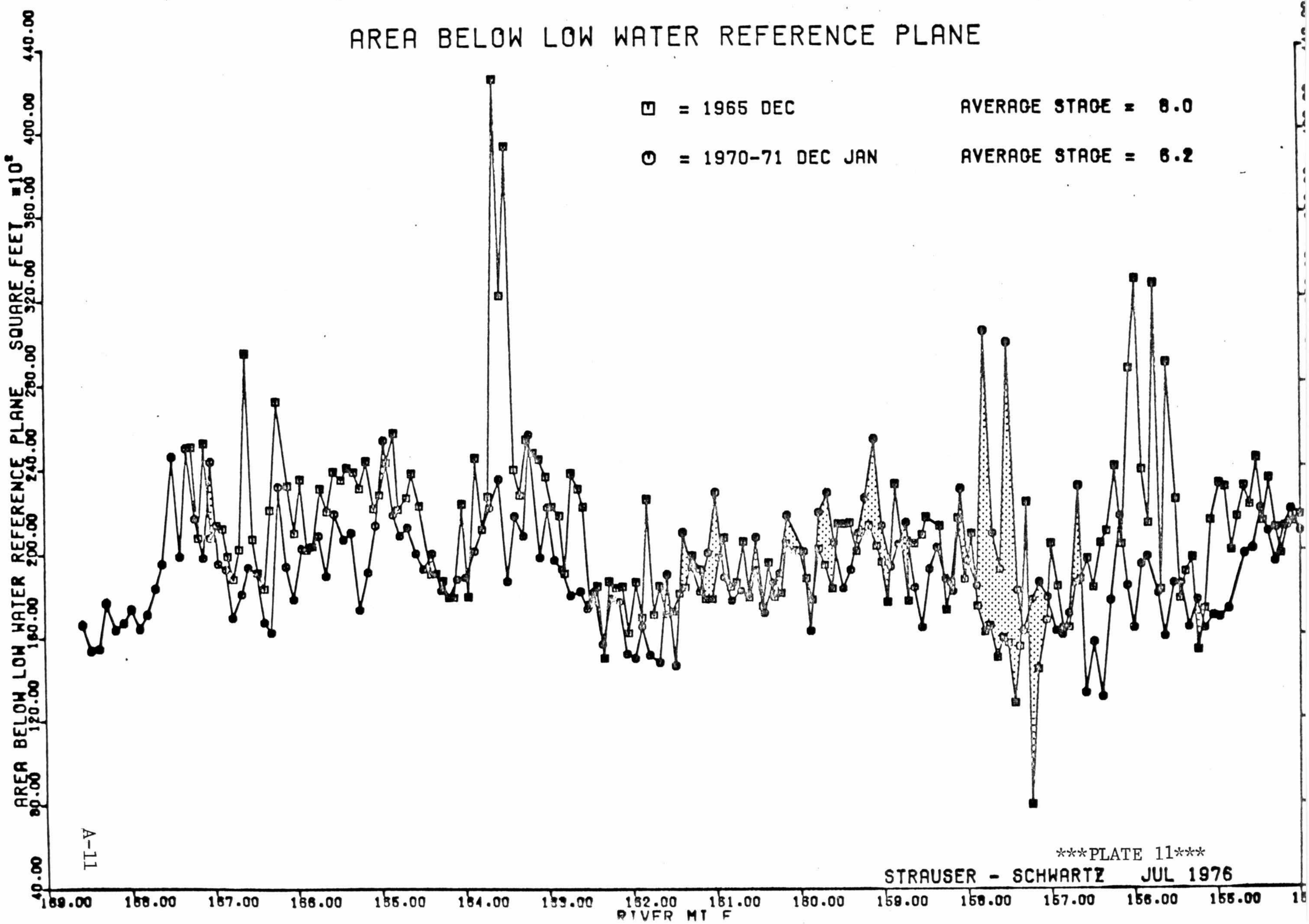

Y = -0.10758 * X + 12.27
18
16
14
12
10
8
4
6
8
10
12
14
16
AVE DEPTH BELOW LWRP VS STAGE ABOVE LWRP
+ 1965 SURVEY
1970-71 SURVEY
1973 SURVEY
X 1975 SURVEY

PLATE 10



AREA BELOW LOW WATER REFERENCE PLANE
= 1965 DEC
AVERAGE STAGE = 8.0
= 1970-71 DEC JAN
AVERAGE STAGE = 6.2
AREA BELOW LOW WATER REFERENCE PLANE SQUARE FEET ×10²
RIVER MILE
STRAUSER - SCHWARTZ JUL 1976

PLATE 11

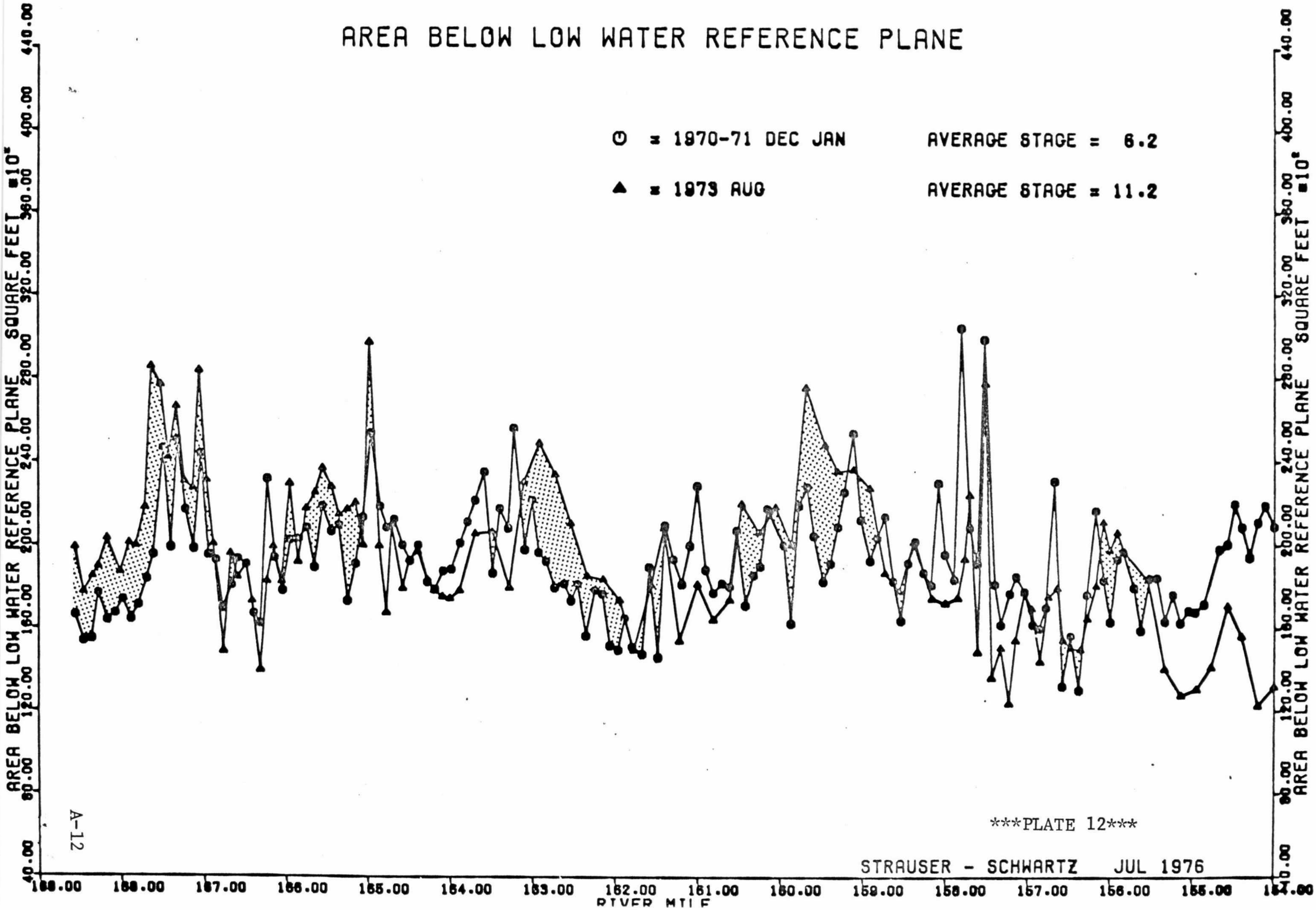

AREA BELOW LOW WATER REFERENCE PLANE
⊙ = 1970-71 DEC JAN
AVERAGE STAGE = 6.2
▲ = 1973 AUG
AVERAGE STAGE = 11.2
AREA BELOW LOW WATER REFERENCE PLANE SQUARE FEET ×10²
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
168.00
167.00
166.00
165.00
164.00
163.00
162.00
161.00
160.00
159.00
158.00
157.00
156.00
155.00
154.00
RIVER MILE
STRAUSER - SCHWARTZ JUL 1976

PLATE 12

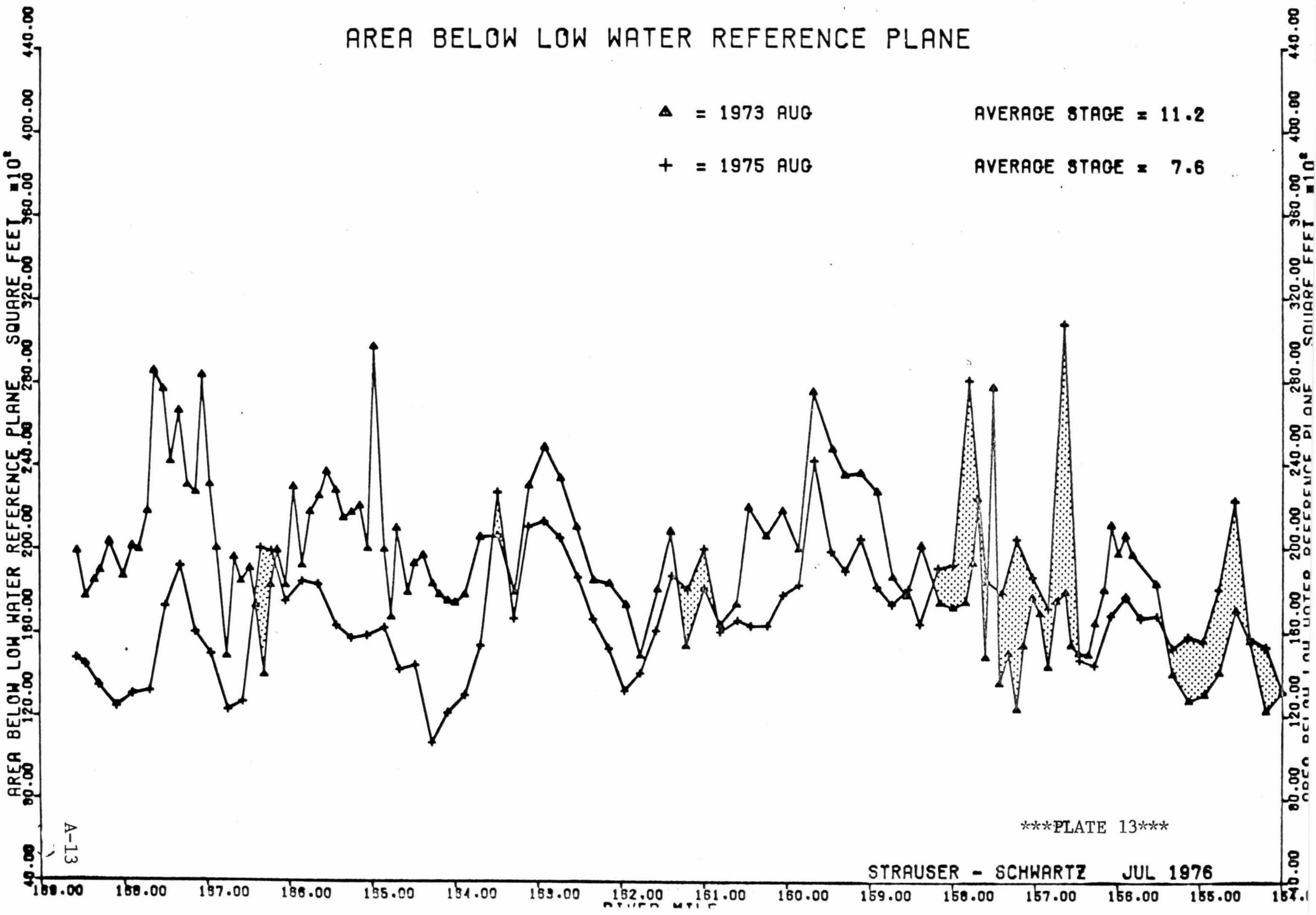
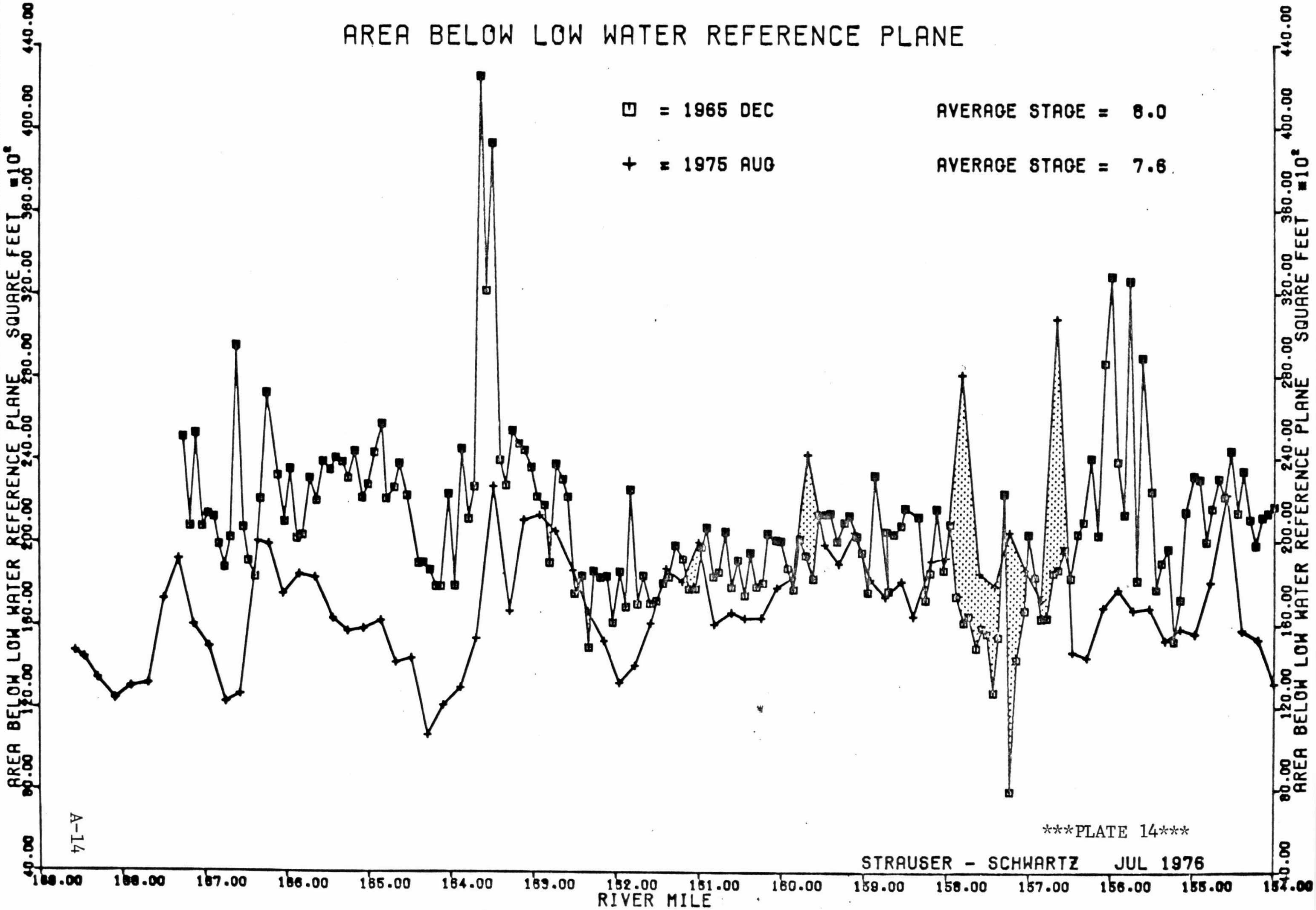
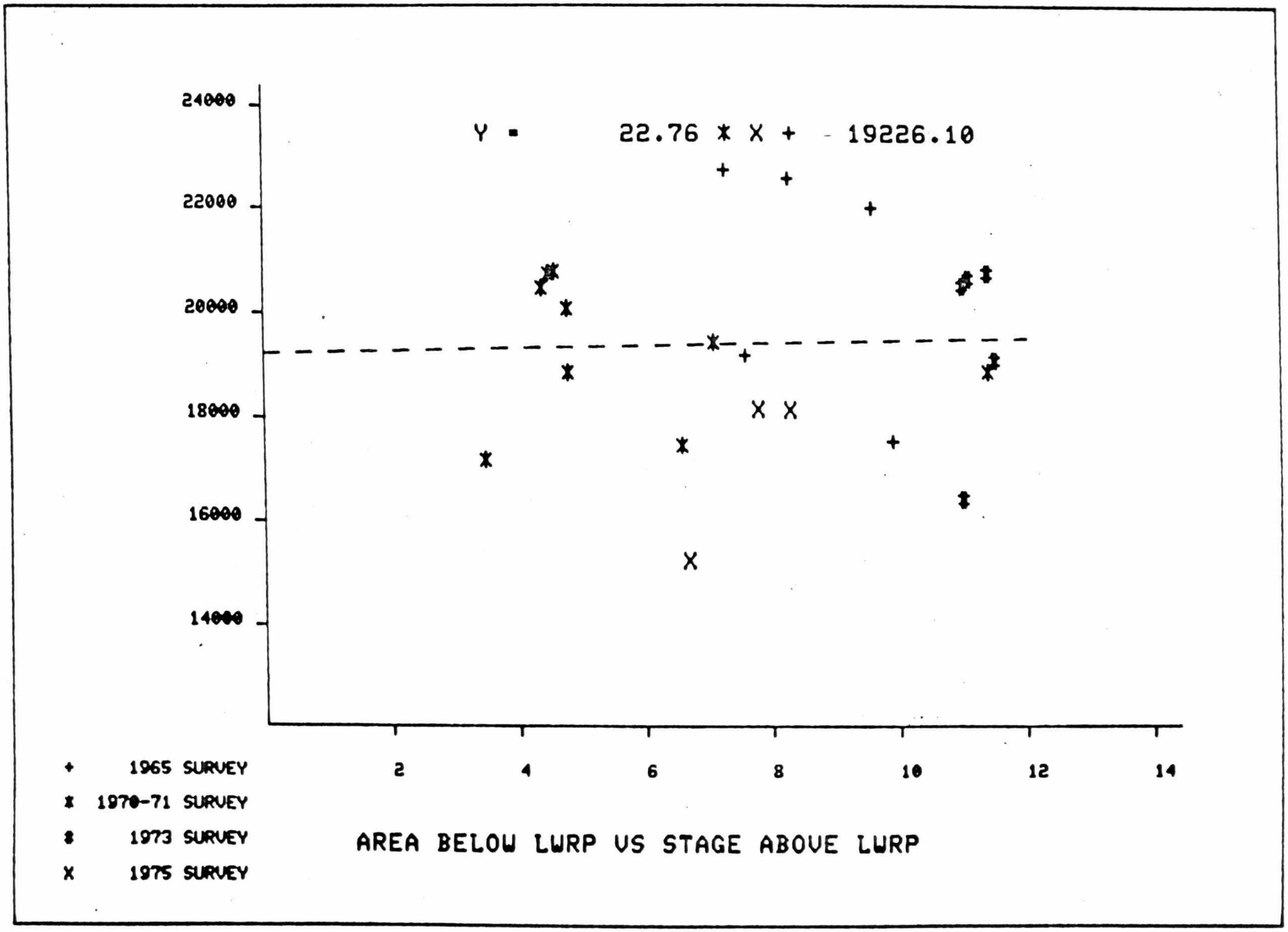

AREA BELOW LOW WATER REFERENCE PLANE
▲ = 1973 AUG
+ = 1975 AUG
AVERAGE STAGE = 11.2
AVERAGE STAGE = 7.6
AREA BELOW LOW WATER REFERENCE PLANE SQUARE FEET *10²
RIVER MILE
STRAUSER - SCHWARTZ JUL 1976

PLATE 13


AREA BELOW LOW WATER REFERENCE PLANE
= 1965 DEC
+ = 1975 AUG
AVERAGE STAGE = 8.0
AVERAGE STAGE = 7.6
AREA BELOW LOW WATER REFERENCE PLANE SQUARE FEET *10²
RIVER MILE
PLATE 14
STRAUSER - SCHWARTZ JUL 1976



Y = 22.76 * X + 19226.10
24000
22000
20000
18000
16000
14000
2
4
6
8
10
12
14
+ 1965 SURVEY
* 1970-71 SURVEY
# 1973 SURVEY
X 1975 SURVEY
AREA BELOW LWRP VS STAGE ABOVE LWRP

PLATE 15

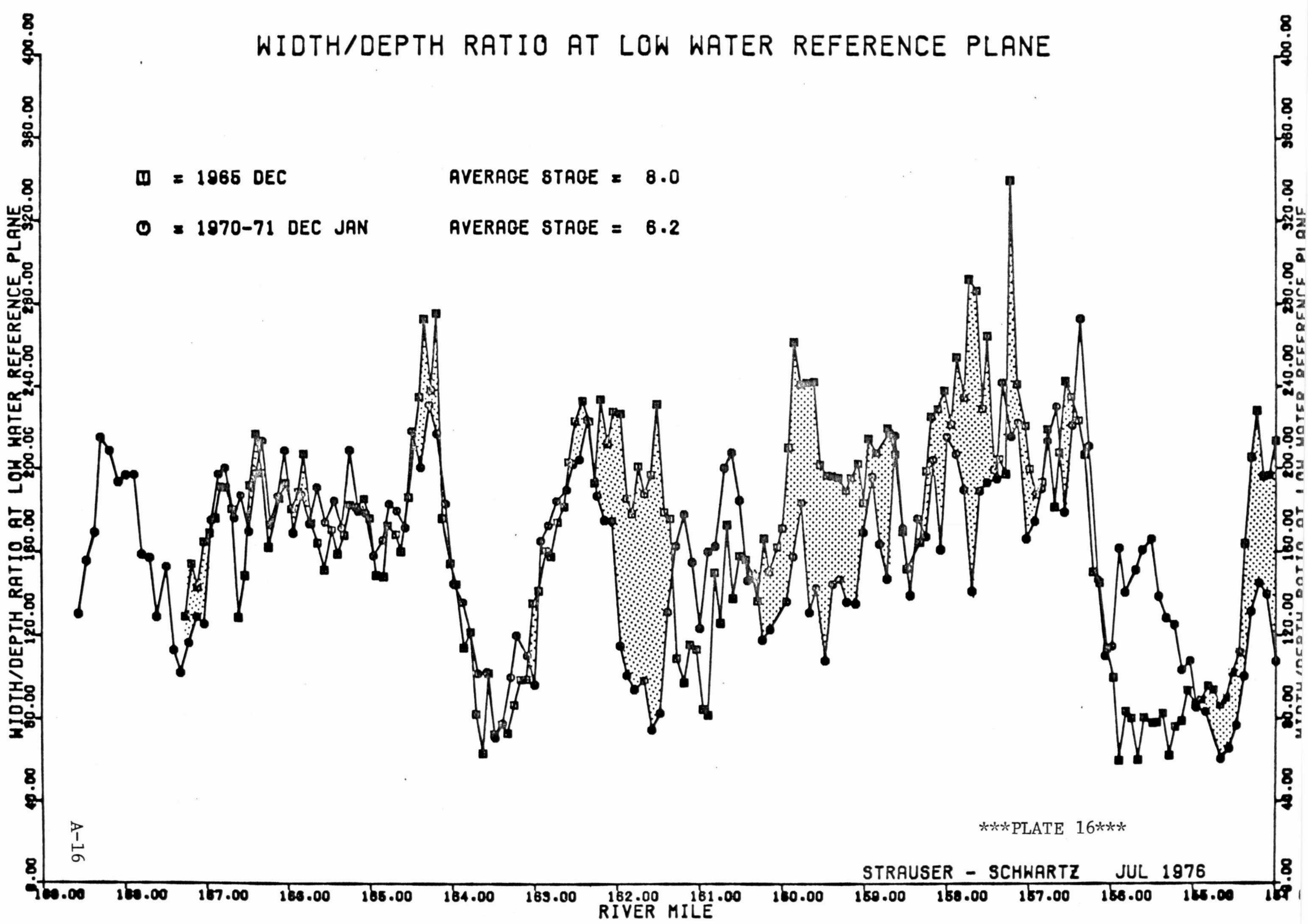
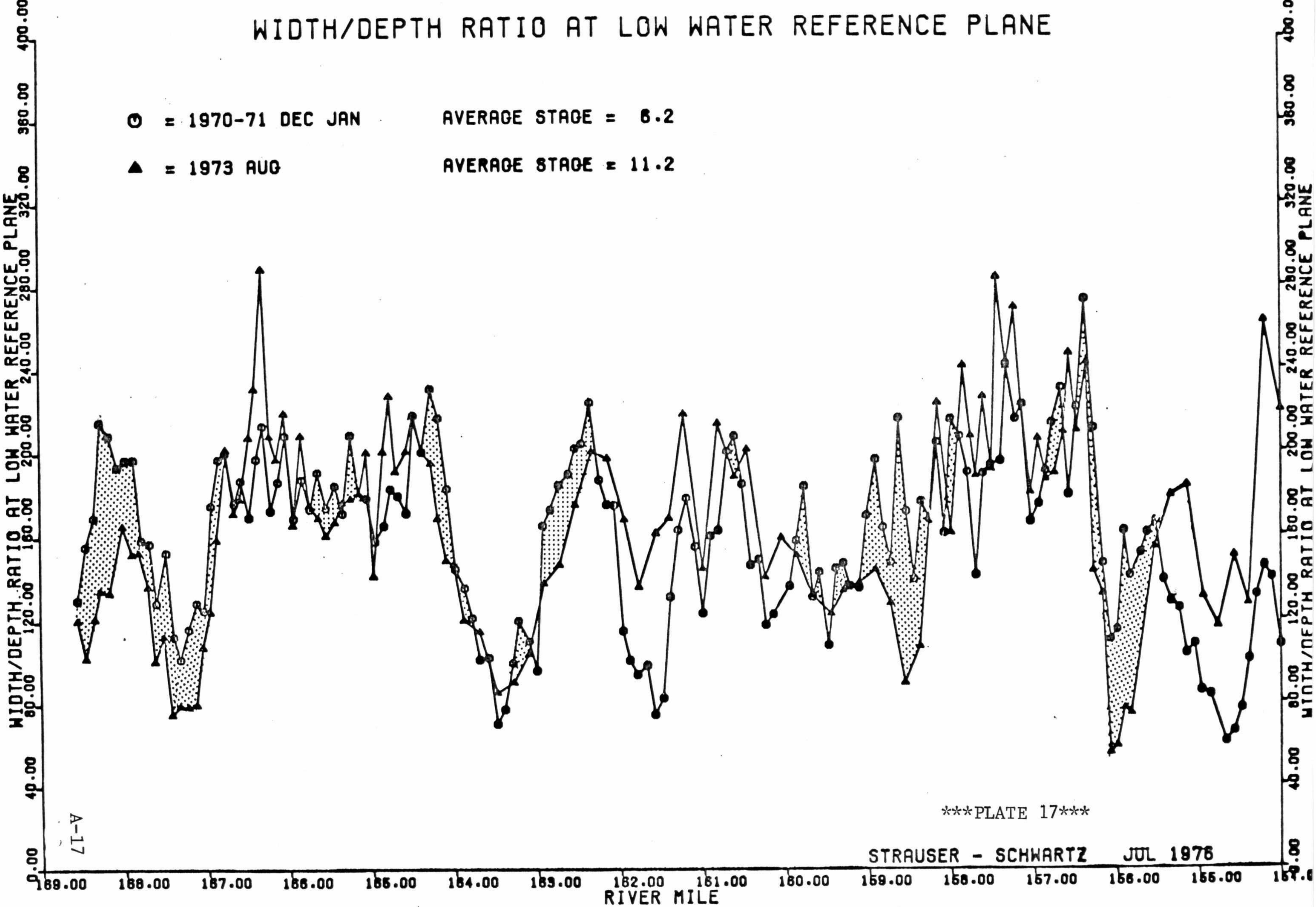

WIDTH/DEPTH RATIO AT LOW WATER REFERENCE PLANE
= 1965 DEC
AVERAGE STAGE = 8.0
= 1970-71 DEC JAN
AVERAGE STAGE = 6.2
WIDTH/DEPTH RATIO AT LOW WATER REFERENCE PLANE
RIVER MILE
STRAUSER - SCHWARTZ JUL 1976

PLATE 16



WIDTH/DEPTH RATIO AT LOW WATER REFERENCE PLANE
⊙ = 1970-71 DEC JAN
AVERAGE STAGE = 6.2
▲ = 1973 AUG
AVERAGE STAGE = 11.2
WIDTH/DEPTH RATIO AT LOW WATER REFERENCE PLANE
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
189.00
188.00
187.00
186.00
185.00
184.00
183.00
182.00
181.00
180.00
159.00
158.00
157.00
156.00
155.00
RIVER MILE
STRAUSER - SCHWARTZ JUL 1976

PLATE 17

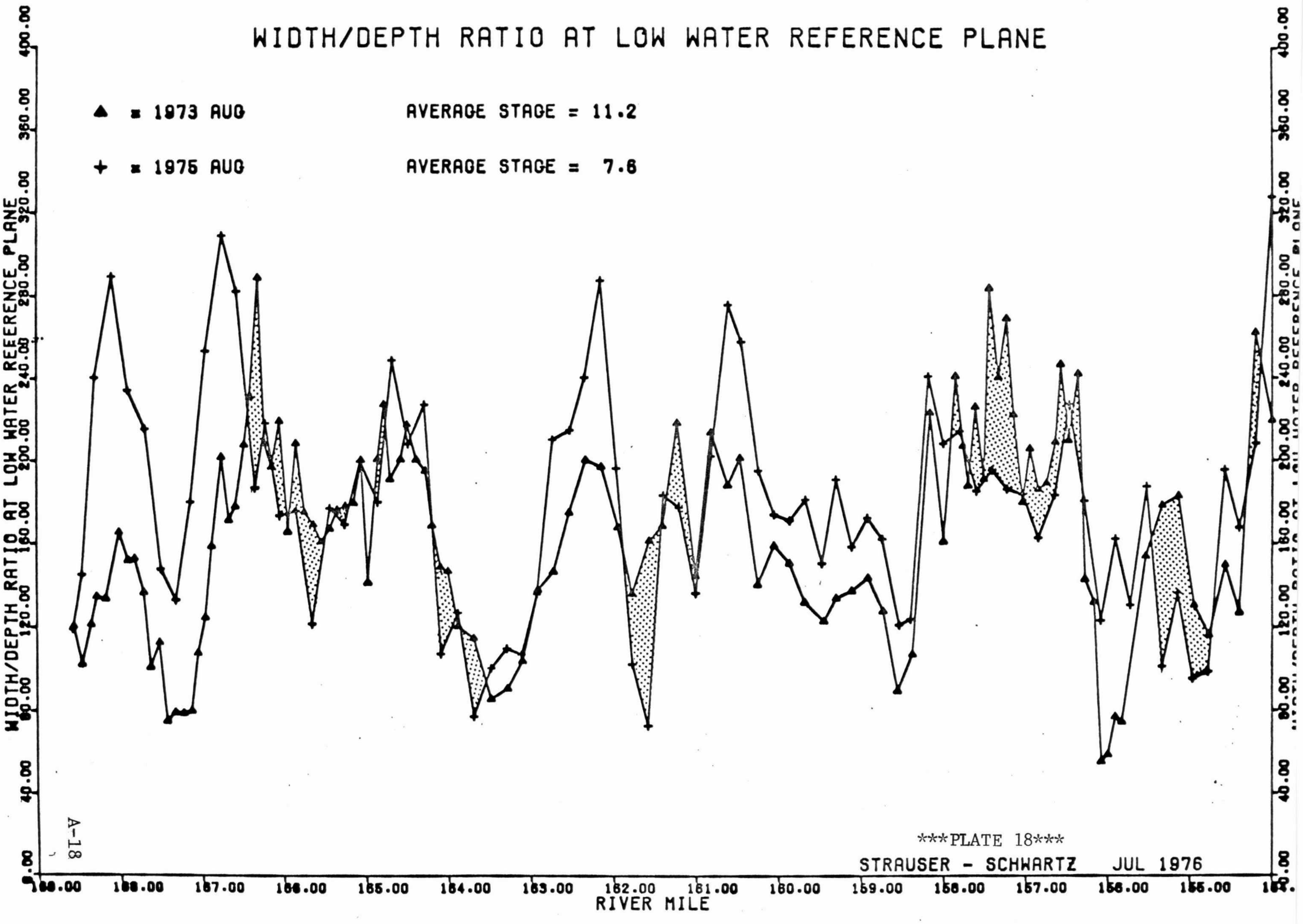


PLATE 18

STRAUSER - SCHWARTZ JUL 1976

A-18

WIDTH/DEPTH RATIO AT LOW WATER REFERENCE PLANE

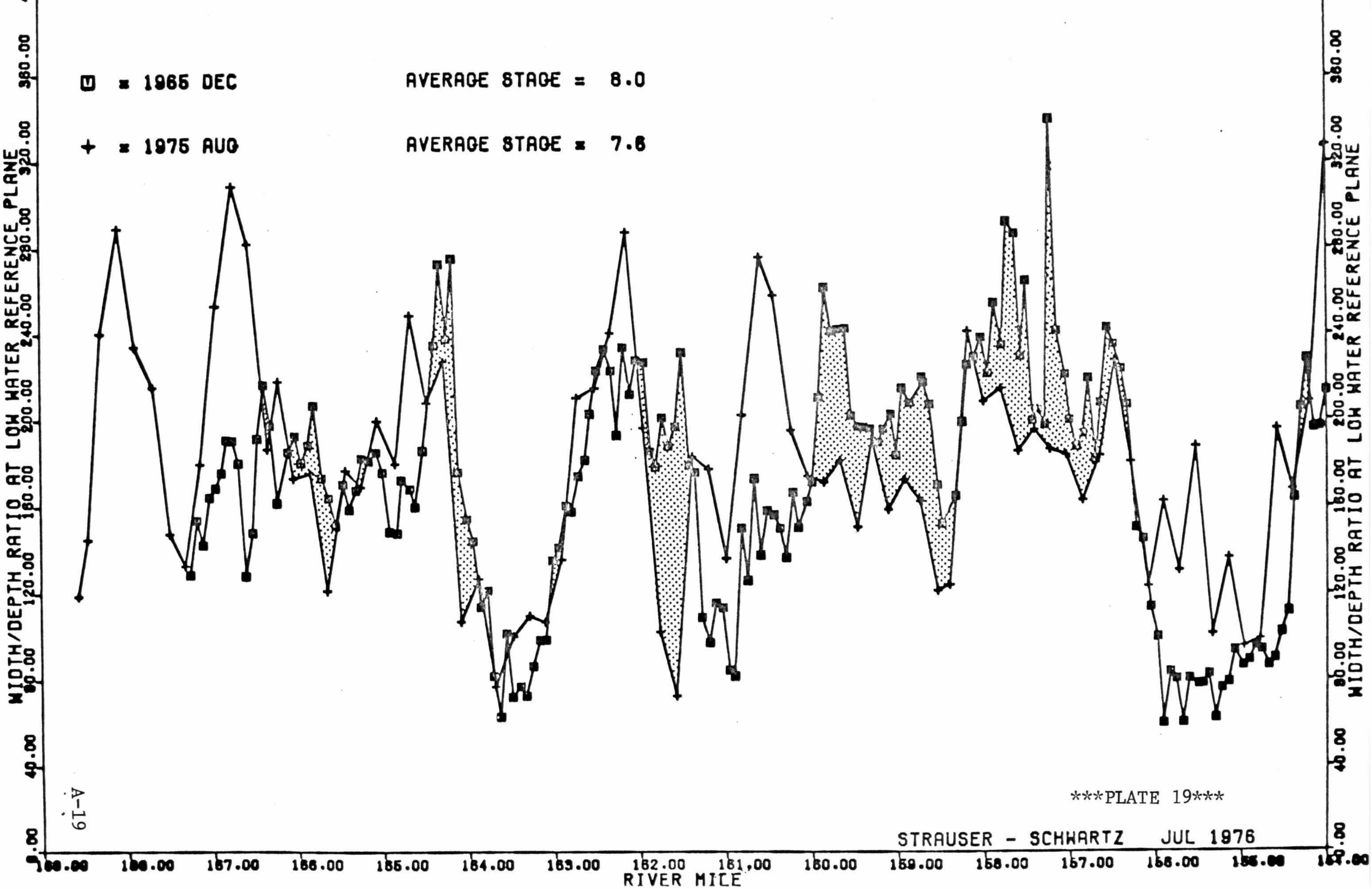
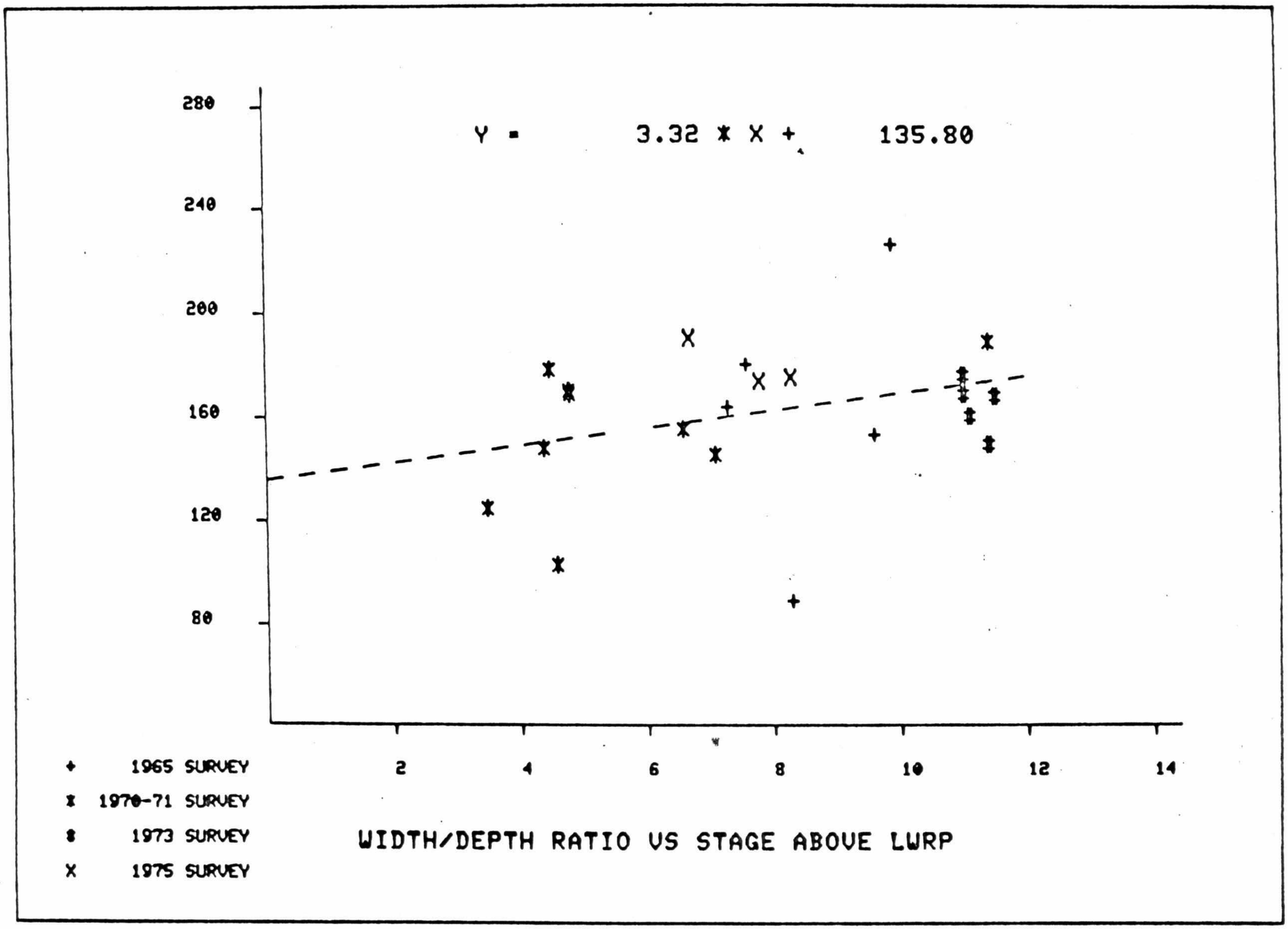


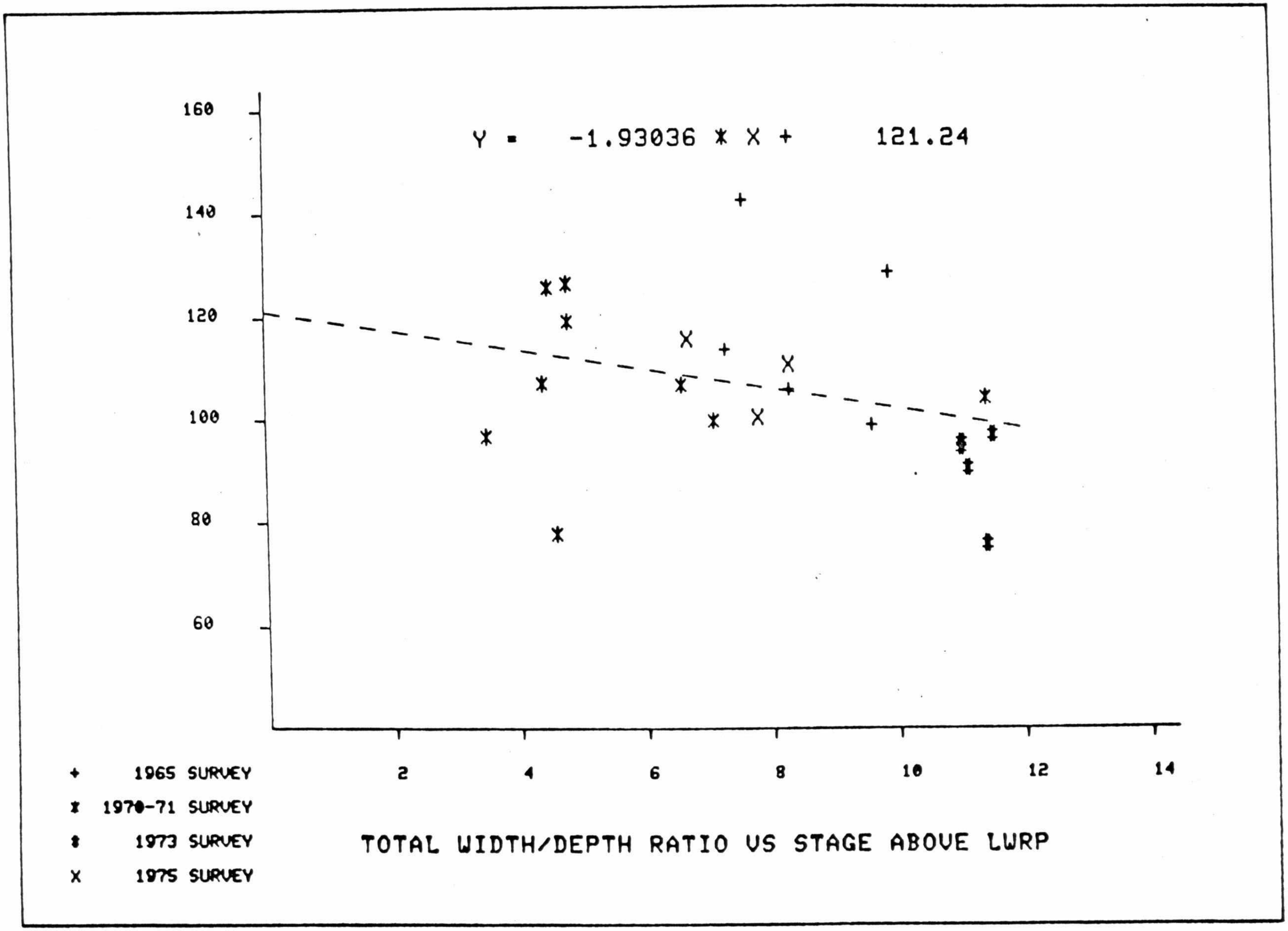
PLATE 19

STRAUSER - SCHWARTZ JUL 1976



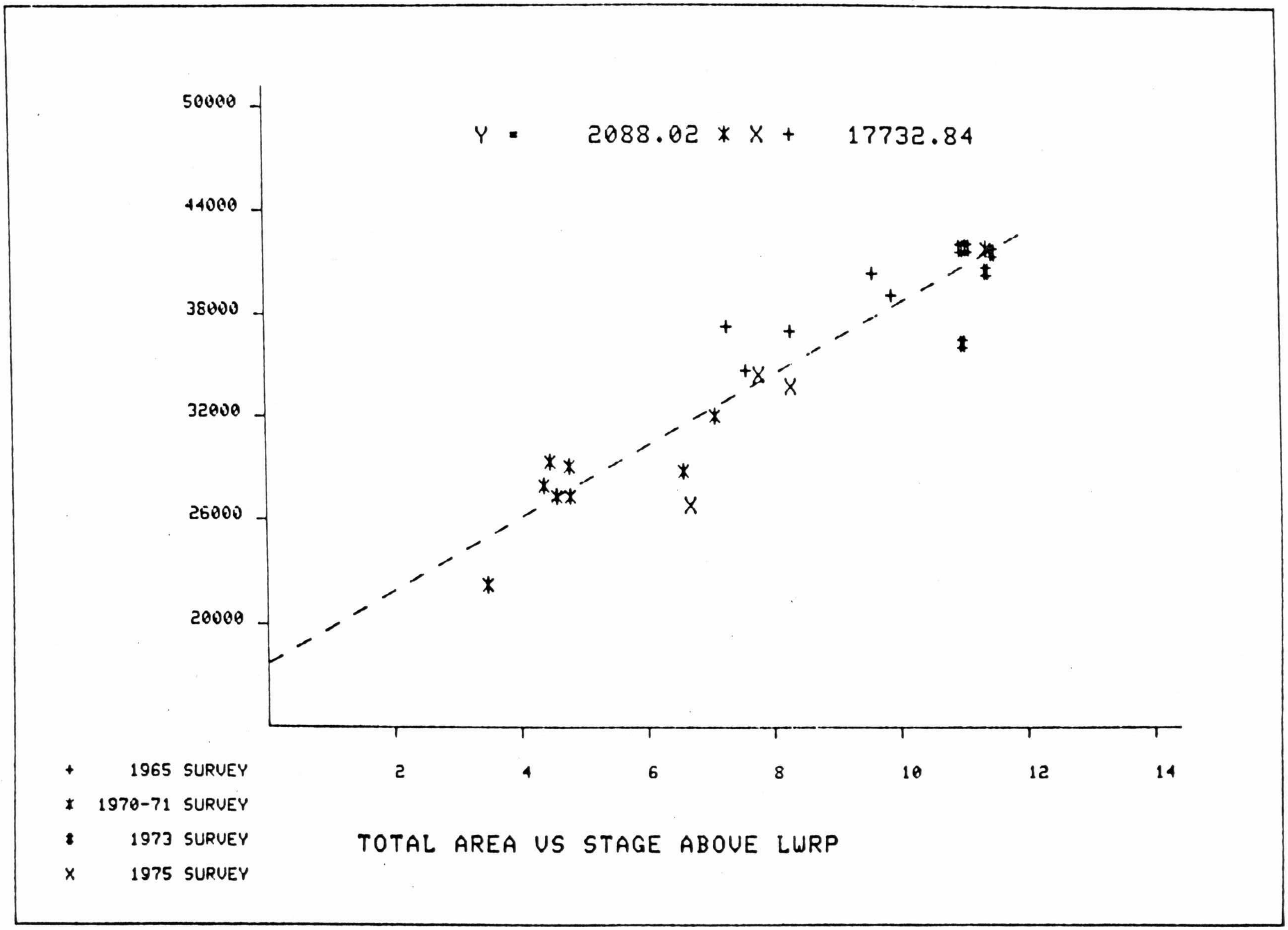
Y = 3.32 * X + 135.80
280
240
200
160
120
80
2
4
6
8
10
12
14
+ 1965 SURVEY
* 1970-71 SURVEY
* 1973 SURVEY
X 1975 SURVEY
WIDTH/DEPTH RATIO VS STAGE ABOVE LWRP

PLATE 20



Y = -1.93036 * X + 121.24
160
140
120
100
80
60
2
4
6
8
10
12
14
+ 1965 SURVEY
1970-71 SURVEY
1973 SURVEY
X 1975 SURVEY
TOTAL WIDTH/DEPTH RATIO VS STAGE ABOVE LWRP

PLATE 21



Y = 2088.02 * X + 17732.84
50000
44000
38000
32000
26000
20000
2
4
6
8
10
12
14
+ 1965 SURVEY
* 1970-71 SURVEY
1973 SURVEY
X 1975 SURVEY
TOTAL AREA VS STAGE ABOVE LWRP

PLATE 22

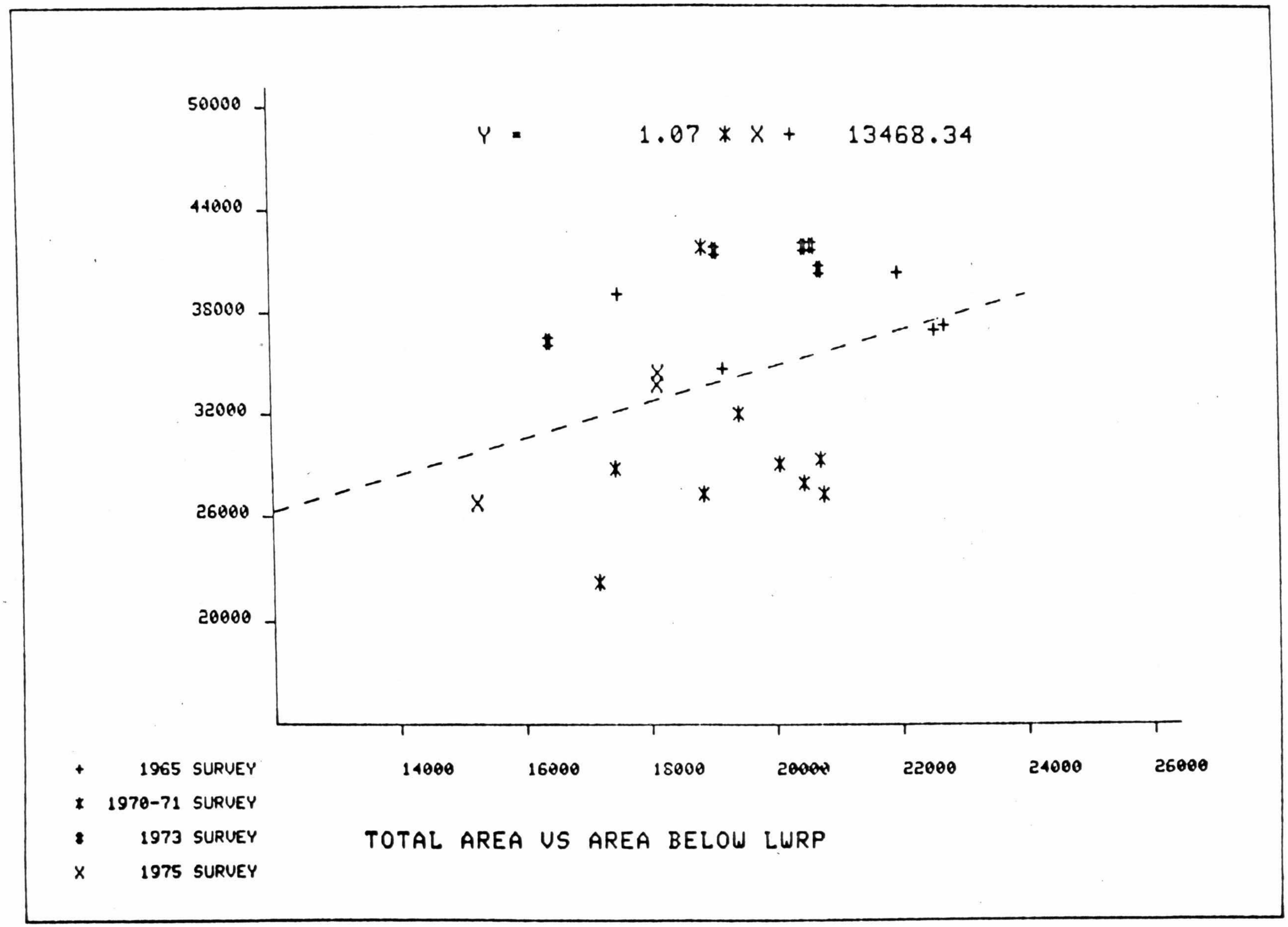

Y = 1.07 * X + 13468.34
50000
44000
38000
32000
26000
20000
14000
16000
18000
20000
22000
24000
26000
+ 1965 SURVEY
* 1970-71 SURVEY
‡ 1973 SURVEY
X 1975 SURVEY
TOTAL AREA VS AREA BELOW LWRP

PLATE 23

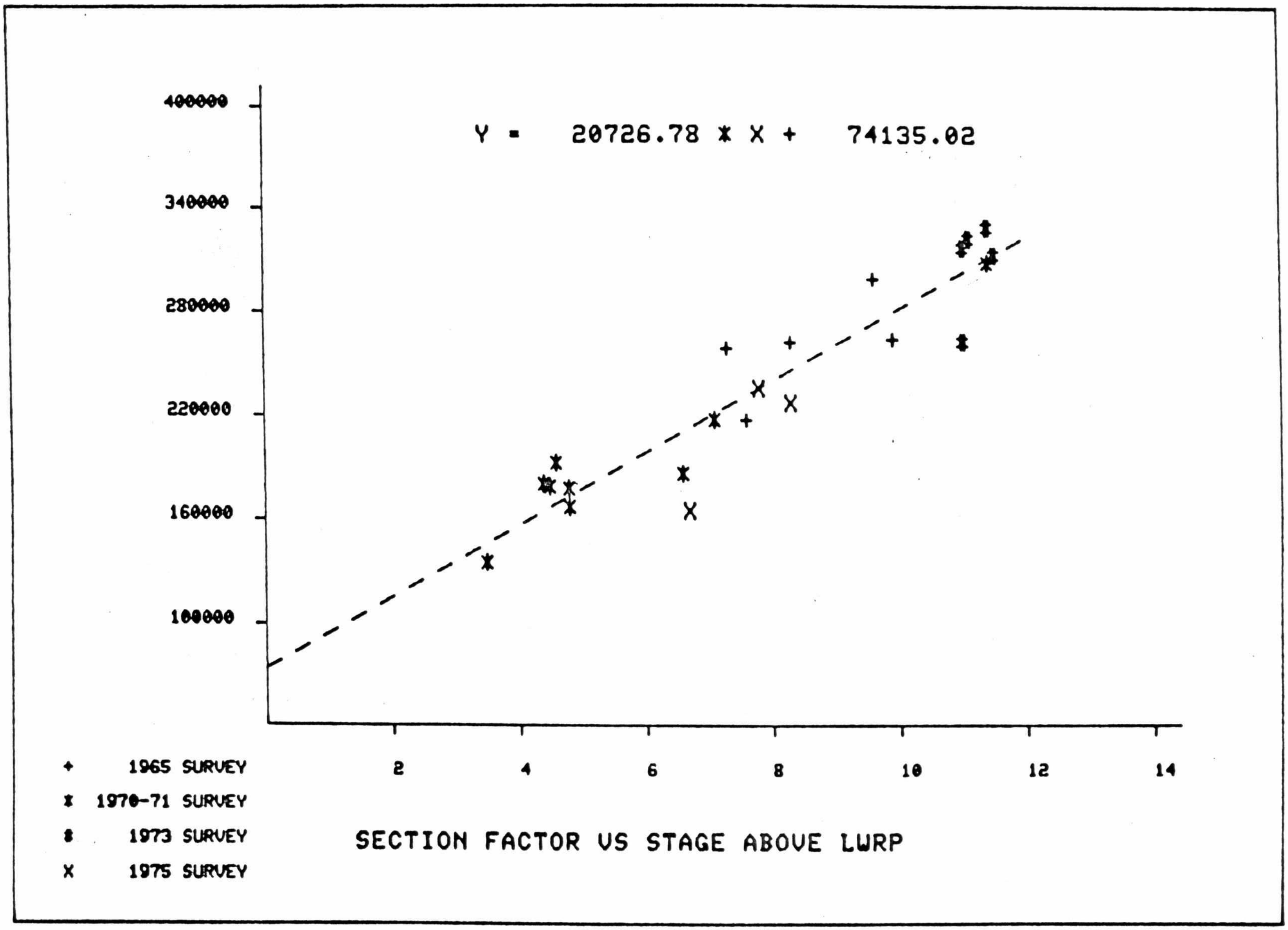

Y = 20726.78 * X + 74135.02
400000
340000
280000
220000
160000
100000
2
4
6
8
10
12
14
+ 1965 SURVEY
* 1970-71 SURVEY
1973 SURVEY
X 1975 SURVEY
SECTION FACTOR VS STAGE ABOVE LWRP

PLATE 24

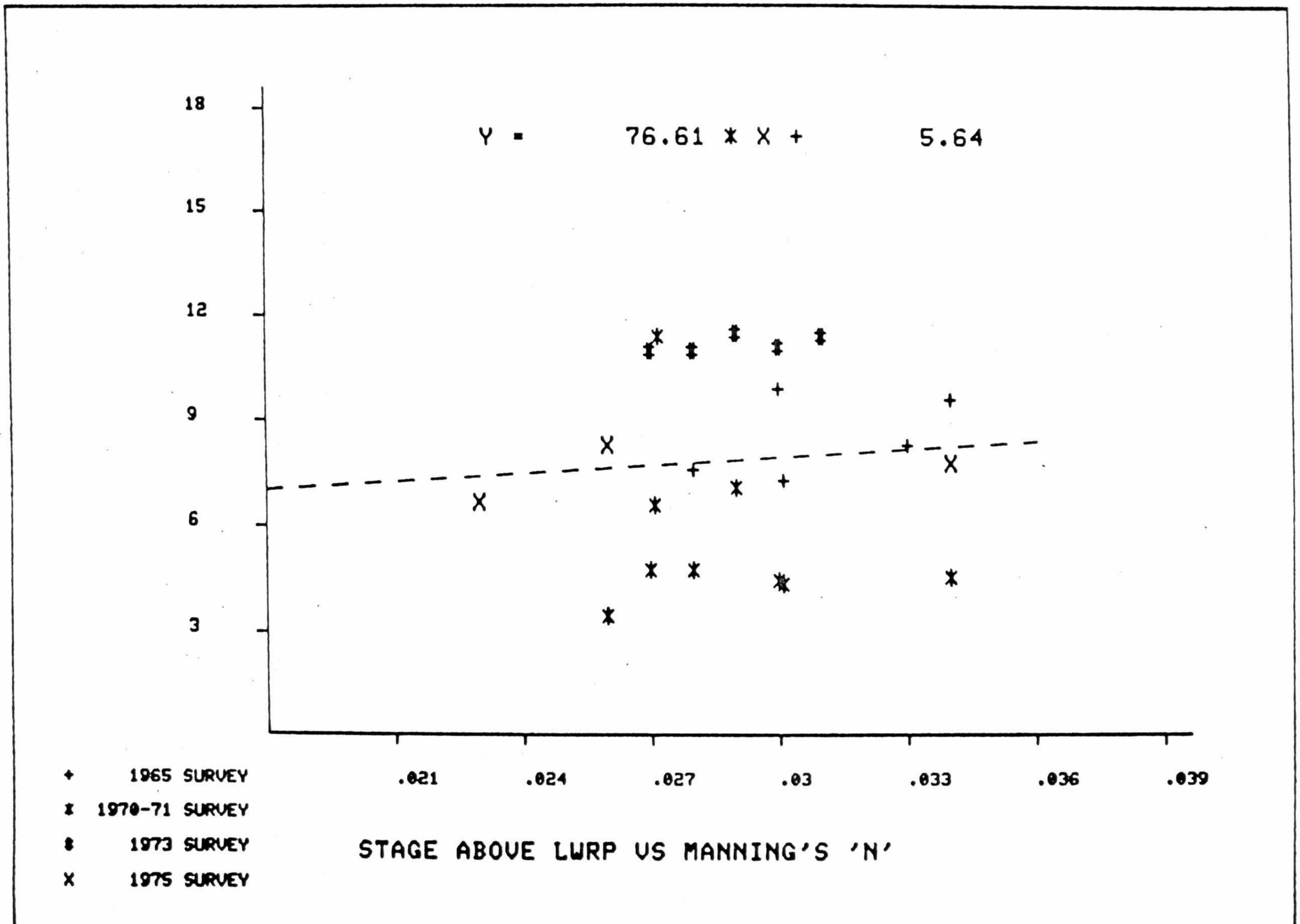

Y = 76.61 * X + 5.64
18
15
12
9
6
3
.021
.024
.027
.03
.033
.036
.039
+ 1965 SURVEY
* 1970-71 SURVEY
‡ 1973 SURVEY
X 1975 SURVEY
STAGE ABOVE LWRP VS MANNING'S 'N'

PLATE 25

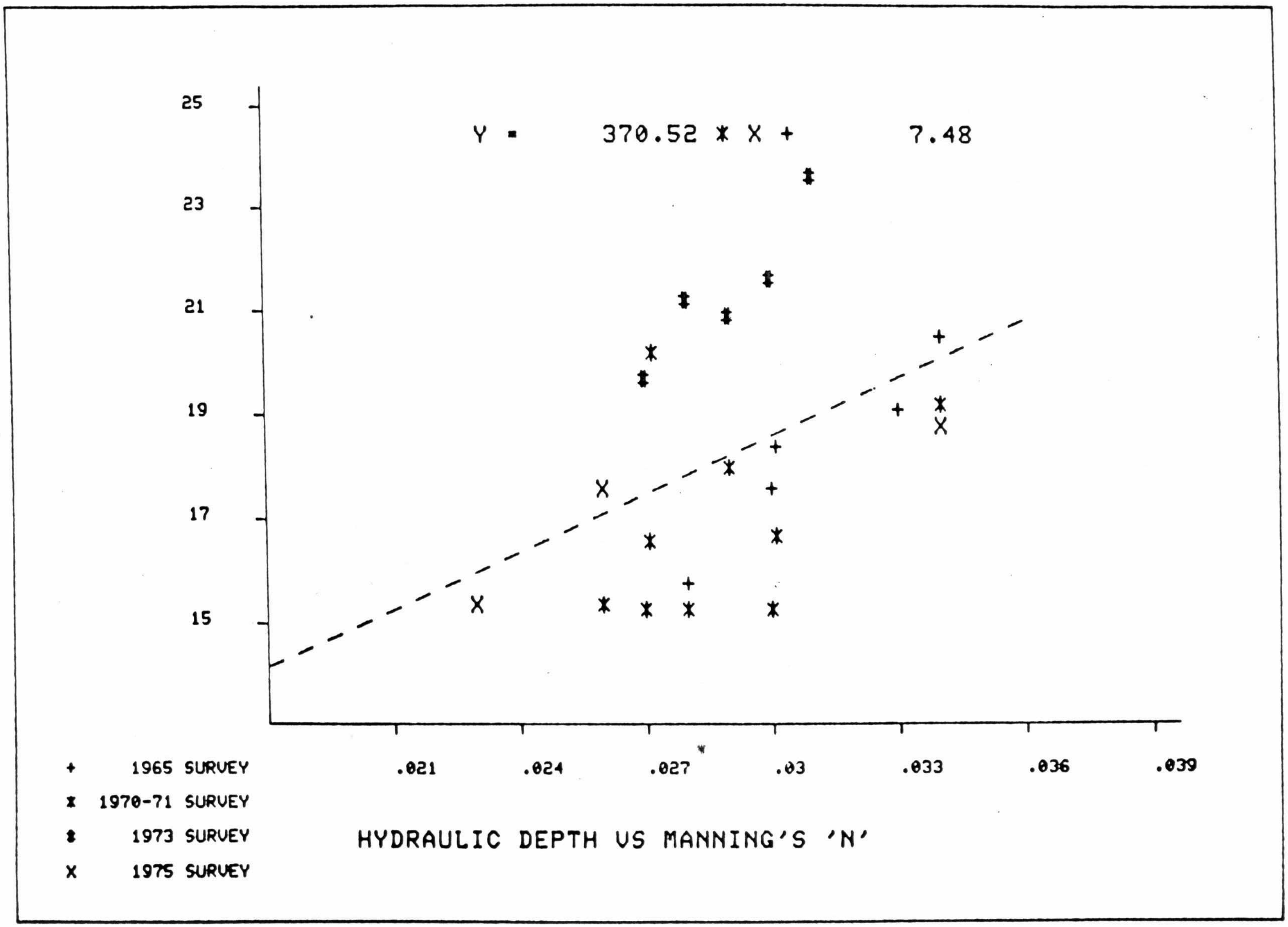
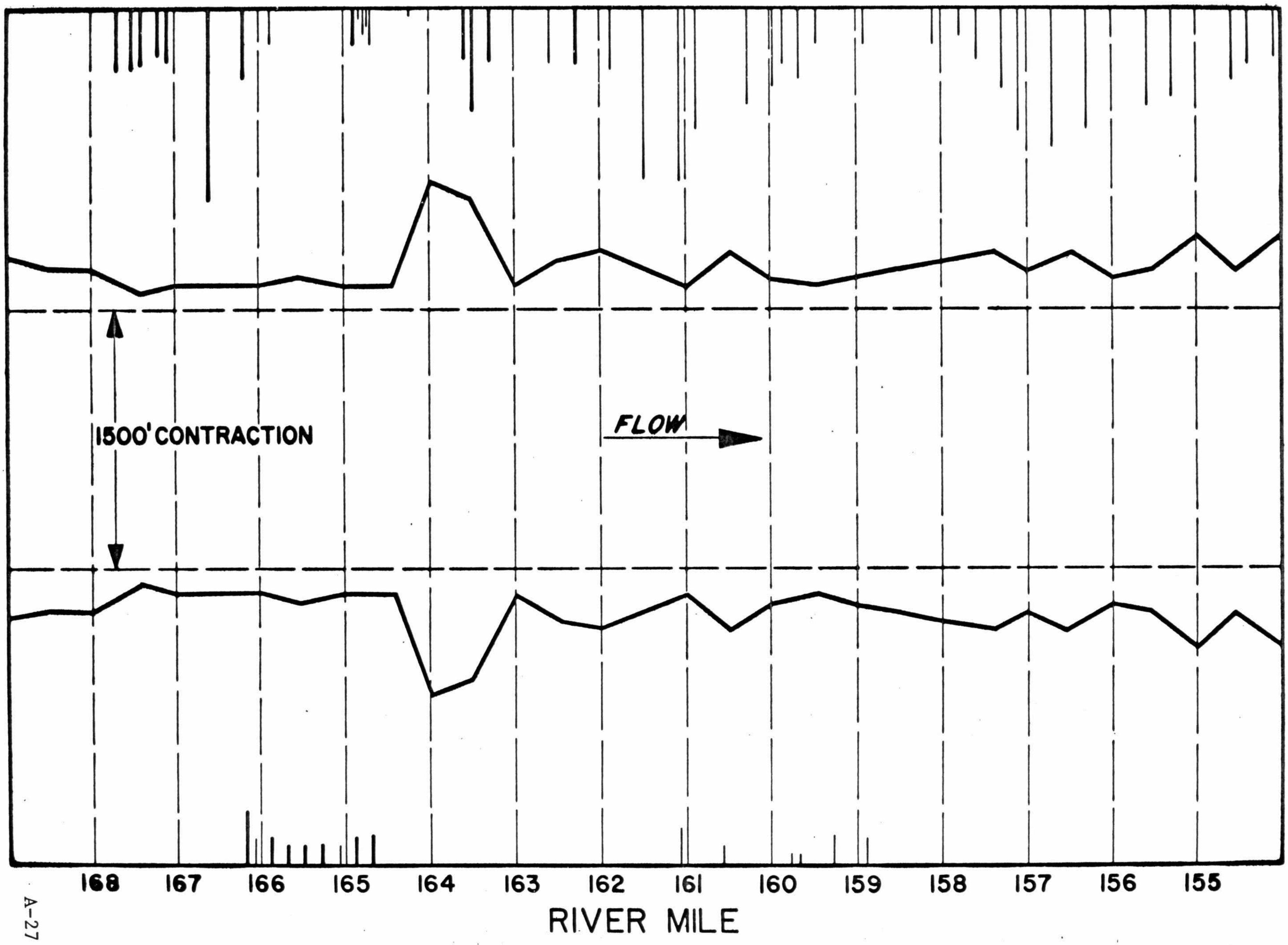
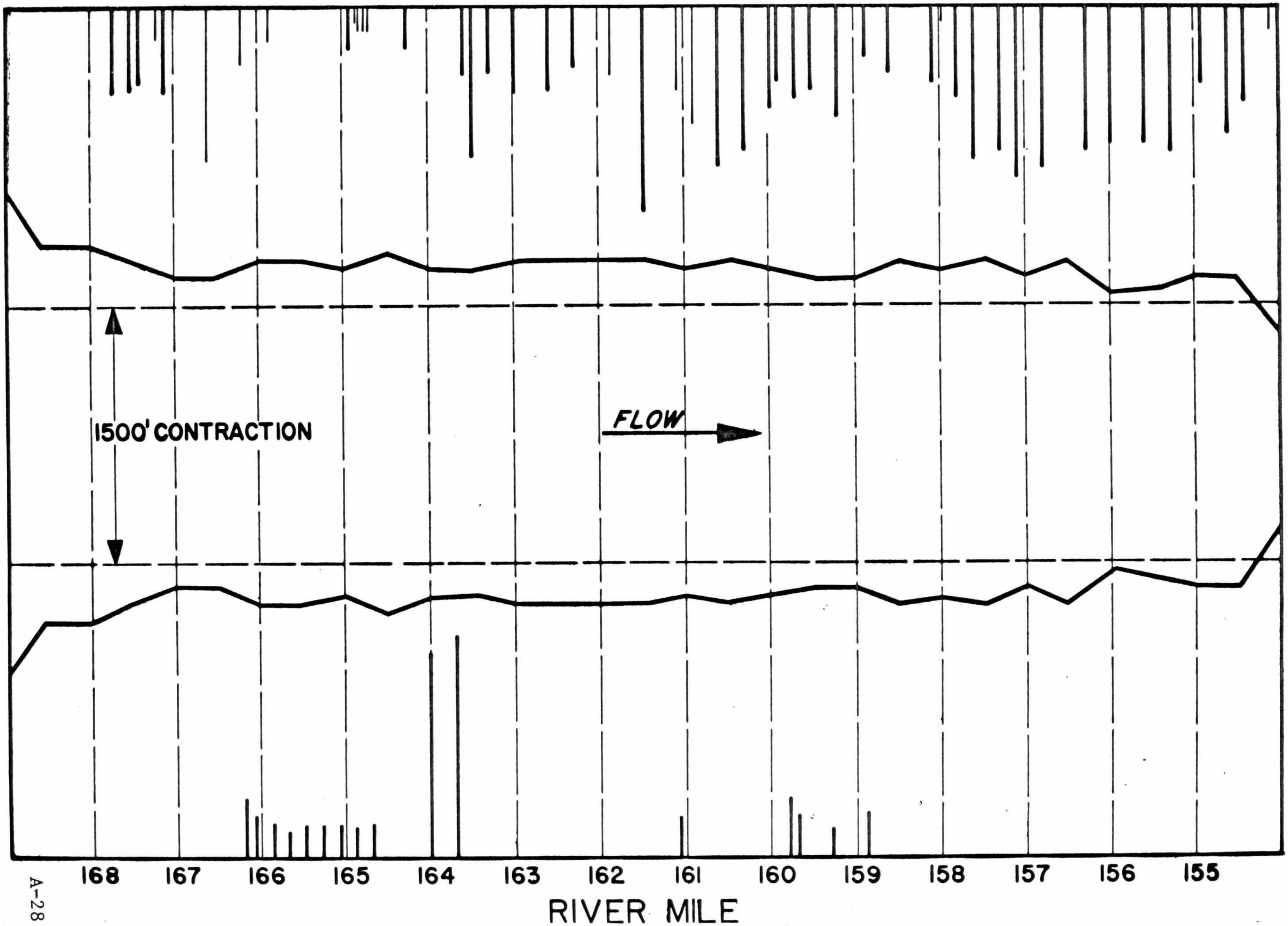

Y = 370.52 * X + 7.48
25
23
21
19
17
15
.021
.024
.027
.03
.033
.036
.039
+ 1965 SURVEY
* 1970-71 SURVEY
‡ 1973 SURVEY
X 1975 SURVEY
HYDRAULIC DEPTH VS MANNING'S 'N'

PLATE 26



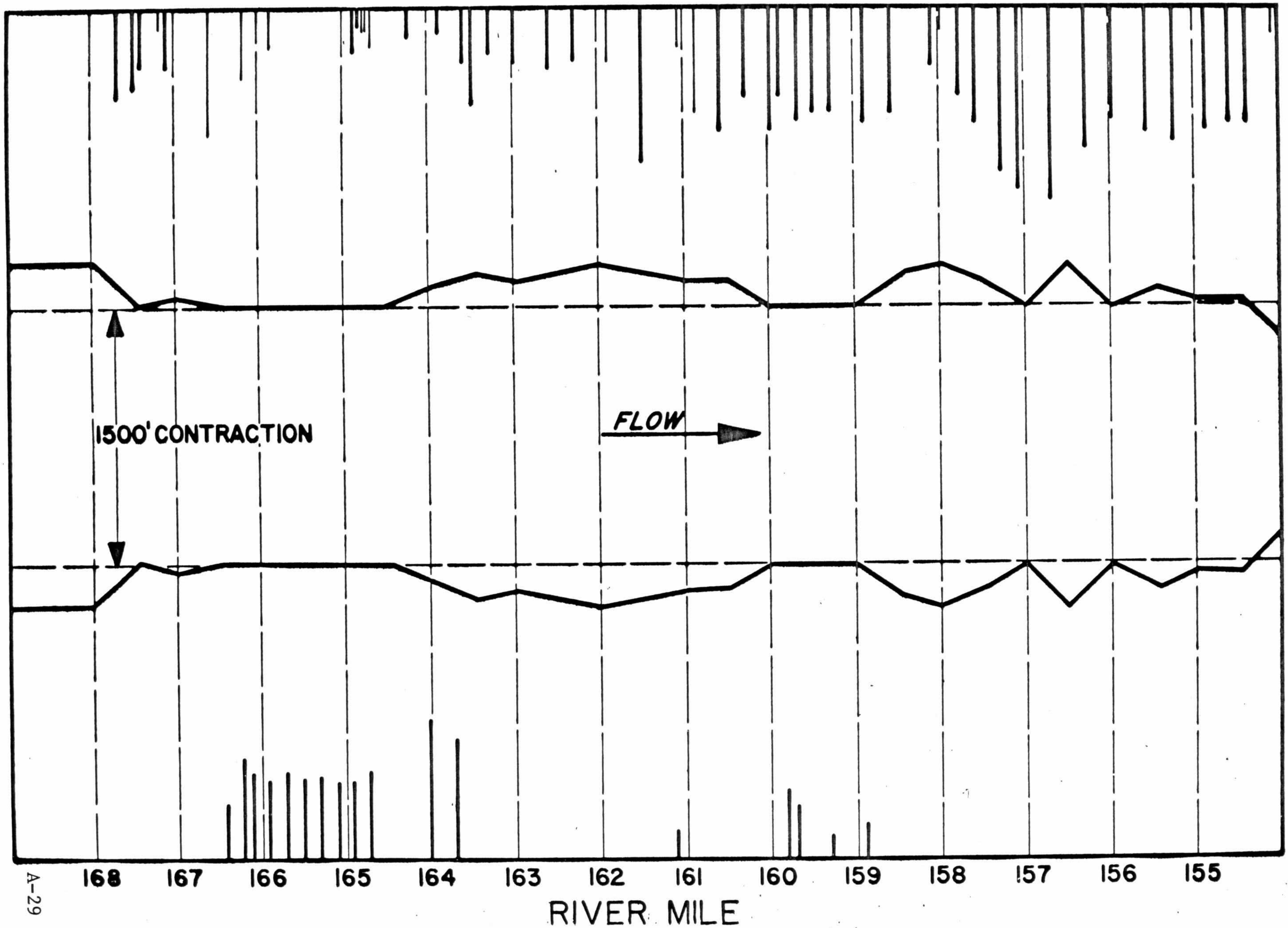
1965

PLATE 27



1970

PLATE 28



1975

PLATE 29