John Stallion 16

U.S. DEPARTMENT OF TRANSPORTATION

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BUREAU OF PUBLIC ROADS

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REASSEMBLY OF POINT PLEASANT BRIDGE DOCUMENTATION OF STRUCTURAL DAMAGE AND IDENTIFICATION OF LABORATORY SPECIMENS

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REASSEMBLY OF POINT PLEASANT BRIDGE

DOCUMENTATION OF STRUCTURAL DAMAGE AND IDENTIFICATION OF LABORATORY SPECIMENS

The Point Pleasant Bridge, often spoken of as the Silver Bridge, suddenly collapsed on the evening of December 15, 1967. The catastrophic failure of this structure that spanned the Ohio River at Point Pleasant, West Virginia, created many unique problems and posed many new questions to the bridge engineering profession. One question that was paramount was, "What caused the bridge to collapse?". Arrangements were made with the Corps of Engineers to perform rescue work and to clear the wreckage from the Ohio River channel as quickly as possible. It was decided that in order to facilitate the study of all possible causes of the failure an attempt should be made to reassemble the bridge, similar to investigations of aircraft accidents. Consequently, a 25-acre reassembly site was leased approximately two miles downstream from the bridge site on the West Virginia shore. Although the exposed wreckage was photographed and sketched to identify it as much as possible, the wreckage below water was more difficult to identify. The Corps of Engineers made available two derrick barges which operated on a 24-hour a day schedule to perform the rescue and salvage work. Assistance in this operation was

provided by divers working for the Dravo Corporation under contract with the Corps of Engineers. The divers found it impossible because of the darkness under water to identify the wreckage except by feel. Because of the need of getting the bodies of victims, and cargoes of trucks, removed as soon as possible, as well as to open the channel for river traffic, some of the bridge members had to be flame cut or broken off during salvage operations. A piece marking crew from the West Virginia Highway Department identified bridge members when they were being removed from the river by painting identifying marks on them. Figure 1 shows the two derrick barges engaged in salvage operations at the site of the collapse working in the area of the West Virginia side span. Barges were used in transporting the wreckage to the reassembly site where it was unloaded and stockpiled on the river bank.

The reassembly site was designed in such a way that the trusses and eyebar chains would be laid out on the ground separated by a gravel road simulating the bridge deck. Additional gravel roads were made so that cranes could pick up the steel from the stockpile on the bank and place it in the proper position on the ground. An aerial view of the reassembly site is shown in Figure 2. The eyebar chains can be distinguished in position on the ground. The north or upstream side of the bridge is nearest the river. The Ohio end of the bridge is at the left side

of the figure. Also the two towers can be seen partially reassembled in separate areas adjacent to the stockpile of salvaged material. The Ohio tower is the one at the right side of the picture. The hanger straps were also placed in a separate location for later identification. Most of the steel at the reassembly site was taken from the river and consisted of the West Virginia side span, the main span and part of the Ohio side span. The section of the bridge that fell on the Ohio bank was stockpiled on the Ohio shore.

Mr. William Domico, bridge engineer for the West Virginia State Roads Commission, was assigned the responsibility by the State to place the steel in its proper location.

During the time the steel was being salvaged, various groups and individuals visited the site to inspect the work. It was discovered that a few critical pieces had not been salvaged. Additional search activities were conducted in an attempt to recover them. Success occurred in locating the outboard piece from the fractured eye of eyebar No. 330, but the pin that had been in the eyebar chain at joint C13N was not recovered even though three separate dredging operations were conducted for that purpose.

During the time the State was laying out the steel at the reassembly site, various groups and individuals were invited to examine it.

Dr. Hechtman, under contract with the Federal Highway Administration, made several examinations. Mr. Scheffey,

Chairman of the Structural Analysis and Tests Working Group, decided that it was essential to identify and catalog the fractured bridge members and the types of fractures that had occurred from the layout at the bridge reassembly site. Consequently, personnel from the Bridges and Structures Specialty Group, Structures and Applied Mechanics Division, were dispatched to Point Pleasant, West Virginia, to perform such a task. The operation was like a giant jigsaw puzzle. Problems existed for determining where each piece fit because of the size of the area (approximately 300 feet by 1500 feet) and from the fact that pieces might be duplicated from two to four to eight times. To identify some of the pieces required a detailed scrutiny. Dimensions were carefully measured. Size and shape of gusset plates, numbers and rows of rivets, and other physical features were compared with a set of as-built drawings of the bridge to properly identify the pieces. Sometimes drip marks on the painted surface were used to indicate which was the top side of a member and at the same time might identify which end was which.

Each piece of steel that had been placed was examined to make sure it had been positioned properly and that pieces still missing in the puzzle were located and placed in positions by crane as shown in Figure 3.

Some problems experienced in identifying the pieces were caused by corrosion of the fractures, the inclement weather, the rank growth of grass and meadow flowers that grew up around the pieces, and the settlement of some of the heavier pieces into the soft ground. All of these problems were resolved to obtain the definite identification of main members of the bridge.

Because of the length of time involved between salvaging operations and identifying and placing steel at the reassembly site, the original identification markings on the steel became indistinguishable. Consequently, new identification numbers were painted on each piece. Pieces were numbered consecutively. The fractured ends of each piece were compared with the ends of the adjoining pieces. In cases where some doubt existed, other pieces that might possibly fit were either brought to the particular location and tried, or in some cases comparisons were made by tracing the outline of the fractured end on paper, photographing it or making a plaster cast of it. Where definite matching occurred between pieces, match marks were painted on the ends. In a few truss panels, it was impossible to identify the correct location for a diagonal, even though two or three were tried. In these instances, the duplicate diagonals were left in these locations and are shown on subsequent photographs and drawings that were made.

At the same time that this work was proceeding, photographs of completed sections were being taken from the platform of a giraffe approximately 30 feet above the steel at the reassembly site as shown in Figure 4. Photographs were taken at approximately 25 foot intervals along each truss. The elevated platform was positioned so that an overlap of approximately 40 percent between photographs was obtained. The 101 photographs obtained were later fitted together into two 25-foot long continuous strips and mounted on kraft paper to form a montage of each side of the bridge. Originals of the two montages are on file at the Fairbank Highway Research Station for reference with this report. In addition to the consecutive identification numbers that showed on the pieces, panel point identification figures and a yardstick for a scale were also put in place for each photograph. In this way each photograph could be clearly identified and the print could be enlarged so that the yardstick scales were the same size for each finished photograph. This adjustment was essential to care for any variations in the height of the giraffe platform and in the focus of the camera.

In addition, all of the fractures in the main chord members and in the chain were photographed at close range from two or more directions to show details. Later, the 476 detail photographs together with the two montages were laid out on a large table at the Fairbank Highway Research

Station and were used to help resolve questions that arose regarding the location of pieces at the reassembly site and the types of fractures that had occurred. Prints of each of these detail photographs are also on file at FHRS for reference with this report.

After the pieces had been positioned, line drawings were made of both the north and south truss and eyebar chain of the bridge. Lengths of each piece and the respective identification number are shown on these field drawings. This information together with information concerning the type of fracture were put together on 17 drawings numbered 1 through 17 and are included as part of this report.

The structural members that formed the floor system, although brought to the reassembly site, were not placed in position on the ground between the north and south trusses. However, Dr. Hechtman examined the floor beam connections in the main chord members to determine the kinds of action that occurred during collapse. The types of failures that occurred at the floor beam ends have been documented in Dr. Hechtman's November 8, 1968 report entitled "Further Examination and Cataloging of Fractures in Wreckage of Point Pleasant Bridge."

The reassembly site was visited from time to time by various members of the Structural Analysis and Tests Working Group and by others invited to inspect the wreckage. Information obtained by some of these was used to identify and place the steel in correct positions or to give expert

opinions concerning fractures or details. In addition to some already named in this report, some of the others who visited the site were Captain William C. Foster of the National Transportation Safety Board, Mr. J. G. Lutz of J. E. Greiner Company, Professor W. L. Starkey of the Ohio State University, Mr. J. A. Bennett of the National Bureau of Standards, Mr. G. W. Steele and Mr. H. B. Hood, Jr., of the State Road Commission of West Virginia, Messrs. F. M. Masters, Jr., and L. C. Bellanca of Modjeski and Masters, Mr. Harold Mindlin of Battelle Memorial Institute Columbus Laboratories, and Mr. William M. Thatcher of American Bridge Company of United States Steel Corporation.

Certain pieces of the bridge were selected by the Structural Analysis and Tests Working Group and shipped to various research groups for further detail examinations and tests. Sometimes complete eyebars or complete joints were selected for this purpose. At other times, only small pieces of a member were selected. The location of the pieces are shown on the 17 drawings together with a code to identify to which laboratory they were sent.

Two of the shorter eyebars from panel U_0-U_1, nominal length 25 feet 4 inches, one of which had been selected by the Bridges and Structures Group for full scale testing at the National Bureau of Standards, together with pins and spacer rings, were taken by Modjeski and Masters and sent to Lehigh University for tests. A list of these pieces is shown on Drawing No. 1.

Material originally sent to some laboratories such as the National Bureau of Standards in some instances was subsequently divided up and sent to other laboratories for tests. Only the original disposition of the material is shown on the drawings. Subsequent dispositions are described in file letters and other reports.

Information from reports by Dr. Hechtman regarding fractures and other salient details were used for correlating information obtained by the Bridges and Structures Specialty Group and for inclusion on the drawings.

The critically fractured and badly bent hanger box at joint U13N together with both ends of hanger U13C13 were identified at the reassembly site and sent to the Fairbank Highway Research Station for further examination, as shown on the line drawings of Drawing No. 3. Sections of the joints between the hanger box and the top chord were removed by flame cutting and sent to the National Bureau of Standards for tests.

This cataloging of information of the reassembly of the Point Pleasant Bridge together with the documentation of structural damage and identification of laboratory specimens will be used to provide Mr. C. F. Scheffey, Chairman, Structural Analysis and Tests Working Group, with additional information for inclusion in his final report to the National Transportation Safety Board on the Point Pleasant Bridge Investigation.

LIST OF FIGURES

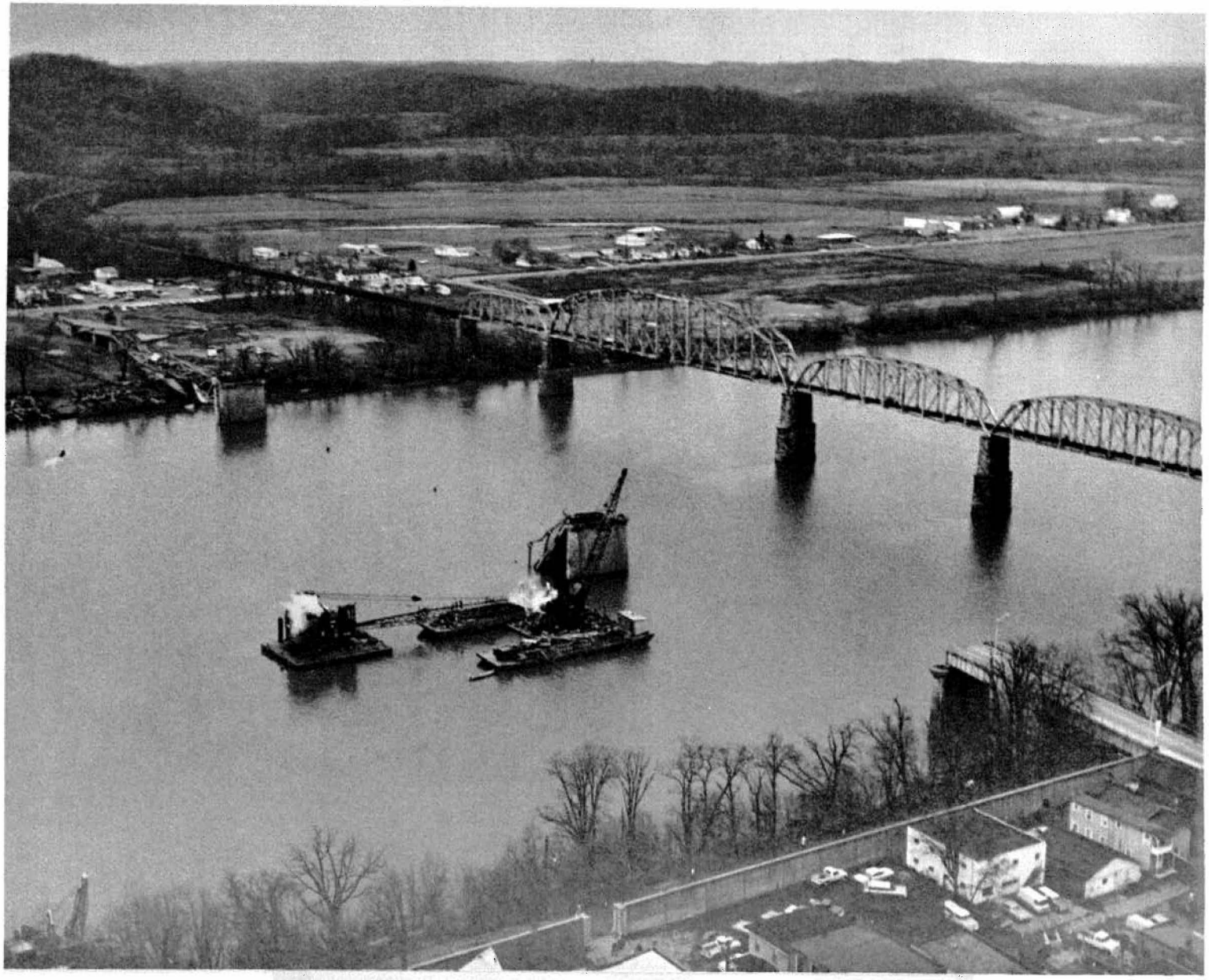


Figure 1 - Derrick barges engaged in salvage operations in the area of West Virginia side span.

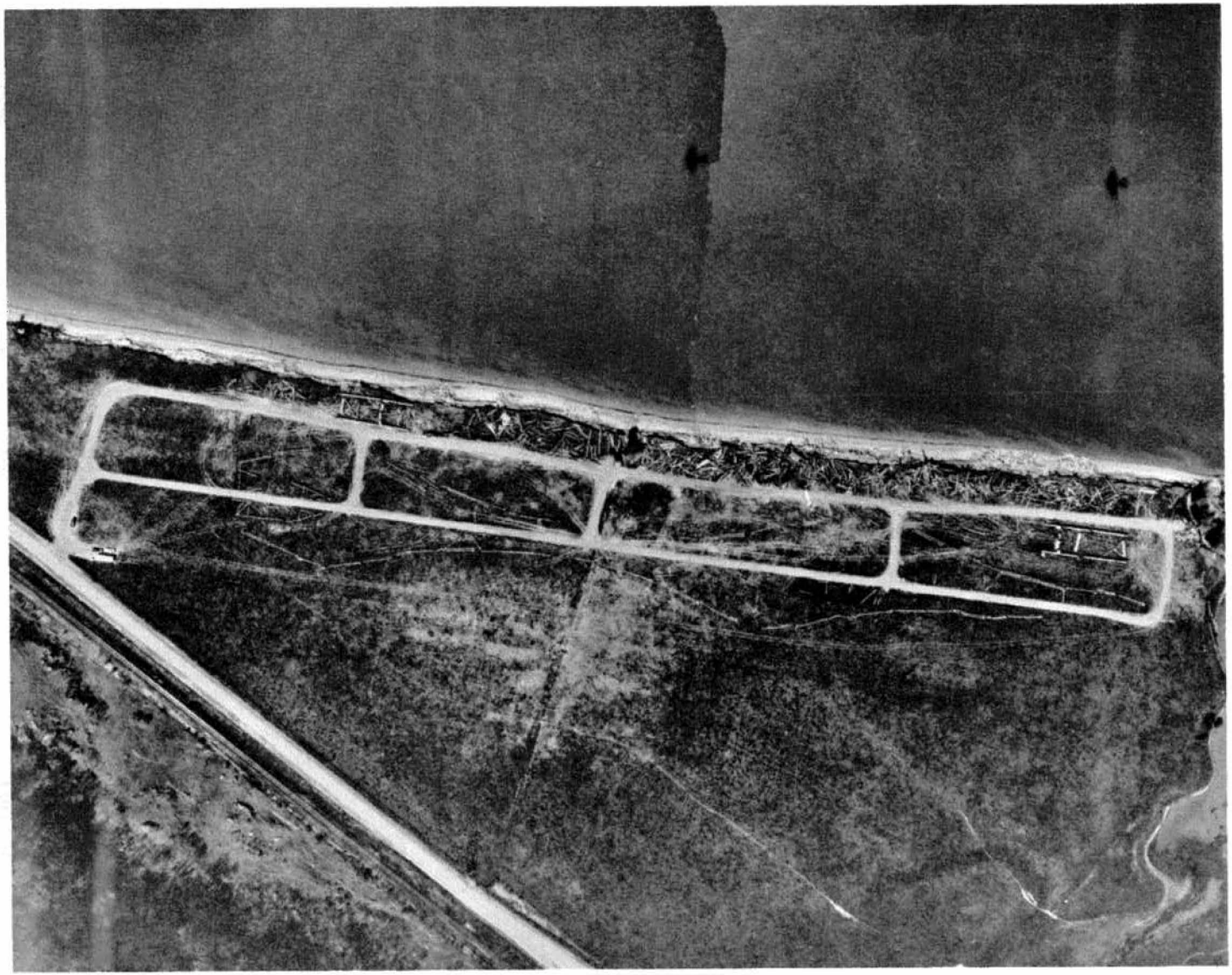


Figure 2 - An aerial view of the reassembly site.

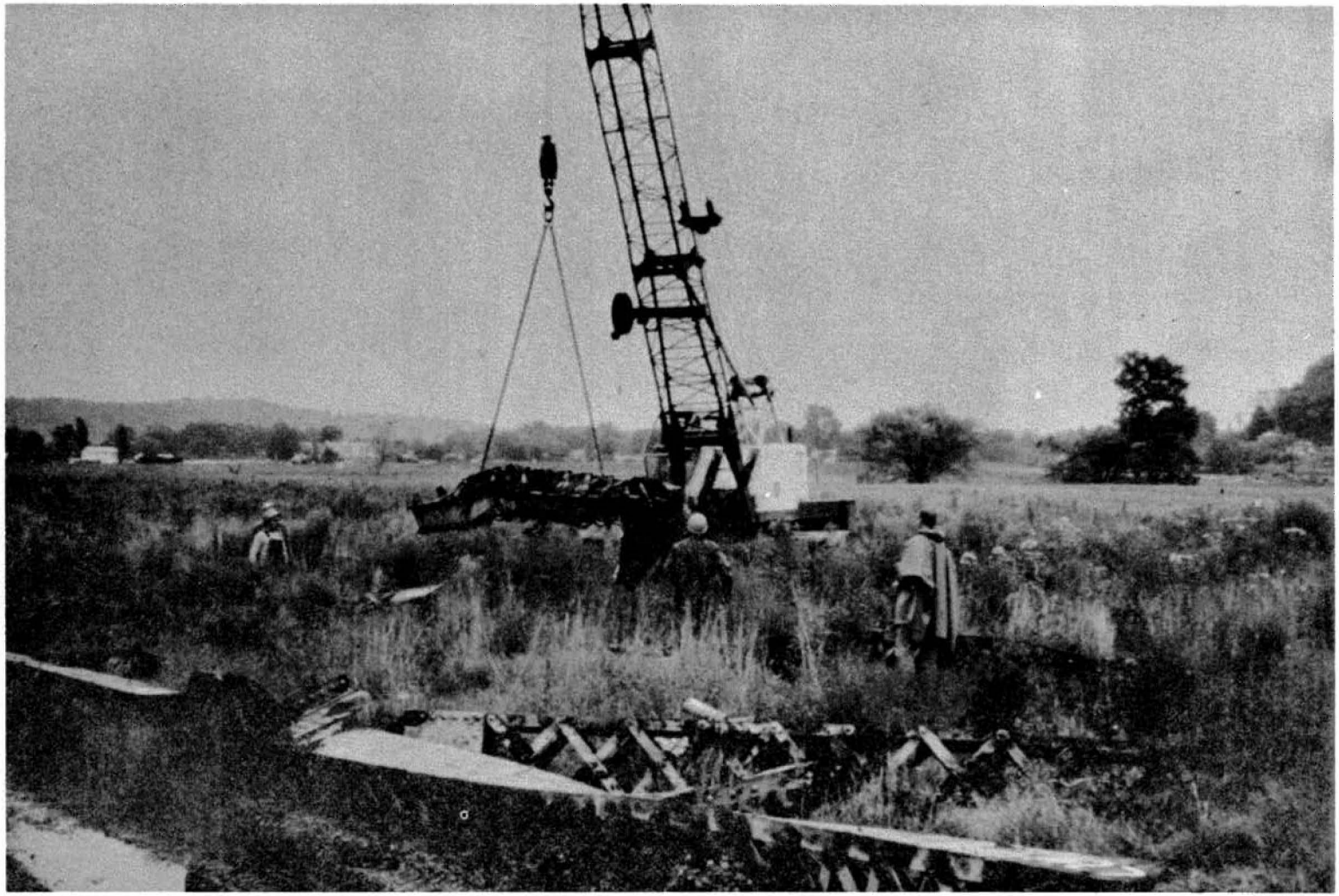


Figure 3 - Crane engaged in reassembly operations; positioning a fractured member in its proper position.

Figure 4 - Photographs being taken of the reassembled bridge pieces.

NOTES

1 All measurements of fracture locations to nearest foot.

2 Samples prefixed with "H" are those selected by R. A. Hechtman and shipped to NBS. Samples prefixed "HH" are those selected by R. A. Hechtman and shipped to BPR.

NOTATION

FC - Flame Cut
CL - Cleavage
SH - Shear
CS - Cleavage and Shear
Ⓢ Positive Match Point
BPR ○ Shipped to BPR (1st ship)
BPR ◯ Shipped to BPR (2nd ship)
NBS △ Shipped to NBS
USS □ Shipped to USS
BTL ⬡ Shipped to BATTELLE

MISCELLANEOUS SAMPLES

Samples selected and shipped to Fritz Engineering Laboratory by Modjeski & Masters

1 Eyebar 25'-4" ± c. c. pin holes, yellow paint number 11 with original 11 1/2" diameter pin assembled in one end.
2 Eyebar 25'-4" ± c. c. pin holes, yellow paint number 10, also numbered MM36
3 2 pins 11 1/2" diameter, 1'-1 1/2" long with 4" ring on each.
4 Pin 11 1/2" diameter, 1'-5 1/2" long with 3" ring
5 Pin 11 1/2" diameter, 1'-5 7/8" long, no ring

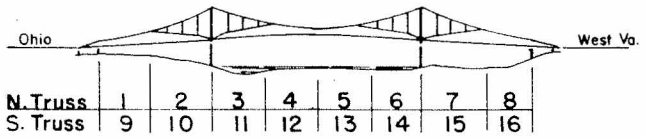
MISCELLANEOUS SAMPLES

Gusset Plate U_3 S BPR ○ HH2
Gusset Plate U_3 S S.R. BPR ○ HH3
Upper end of chain bent post
L_0 U_0 N. side Ohio end NBS △
Short section of 2 eyebars
8' ± and 15' ± long NBS △
Three pins, all the same length that would fit in joint C_{13}
Two pins include hanger plate NBS △
Eyebar 51'-4 3/4" c.c. pin holes, numbered MM32, NBS ⑤
Eyebar 51'-4 3/4" c.c. pin holes, numbered M31, NBS ④
Eyebar 51'-4 3/4" c.c. pin holes, numbered 50, MM15 NBS ③
Eyebar 44'-4 3/4" c.c. pin holes, numbered MM10, NBS ⑥
Retainer cap and bolt BPR ○ HH4, unidentified

MISCELLANEOUS SAMPLES

Eyebar heads from Ohio shore wreckage

From eyebar designated as MM11, BTL ⑩
From eyebar designated as #3, BTL ⑧ & BTL ⑨
From eyebar designated as #5, BTL ⑥ & BTL ⑦
From eyebar designated as #7, BTL ④ & BTL ⑤
From eyebar designated as MM14, BTL ③
From eyebar designated as MM7, BTL ②
From eyebar designated as MM18, BTL ①



LOCATION KEY

TRUSS AND EYEBAR REASSEMBLY WITH FRACTURE NOTES AND SAMPLE LOCATIONS

Appendix A

DR.1

NORTH TRUSS

LOCATION KEY

WRECKAGE IN THIS AREA
INSPECTED AND DOCUMENTED
WHERE IT FELL ON OHIO SHORE

Match Line

Fractured portion of gusset plate NBS

HHI N. gusset PL

N. N. EYEBAR

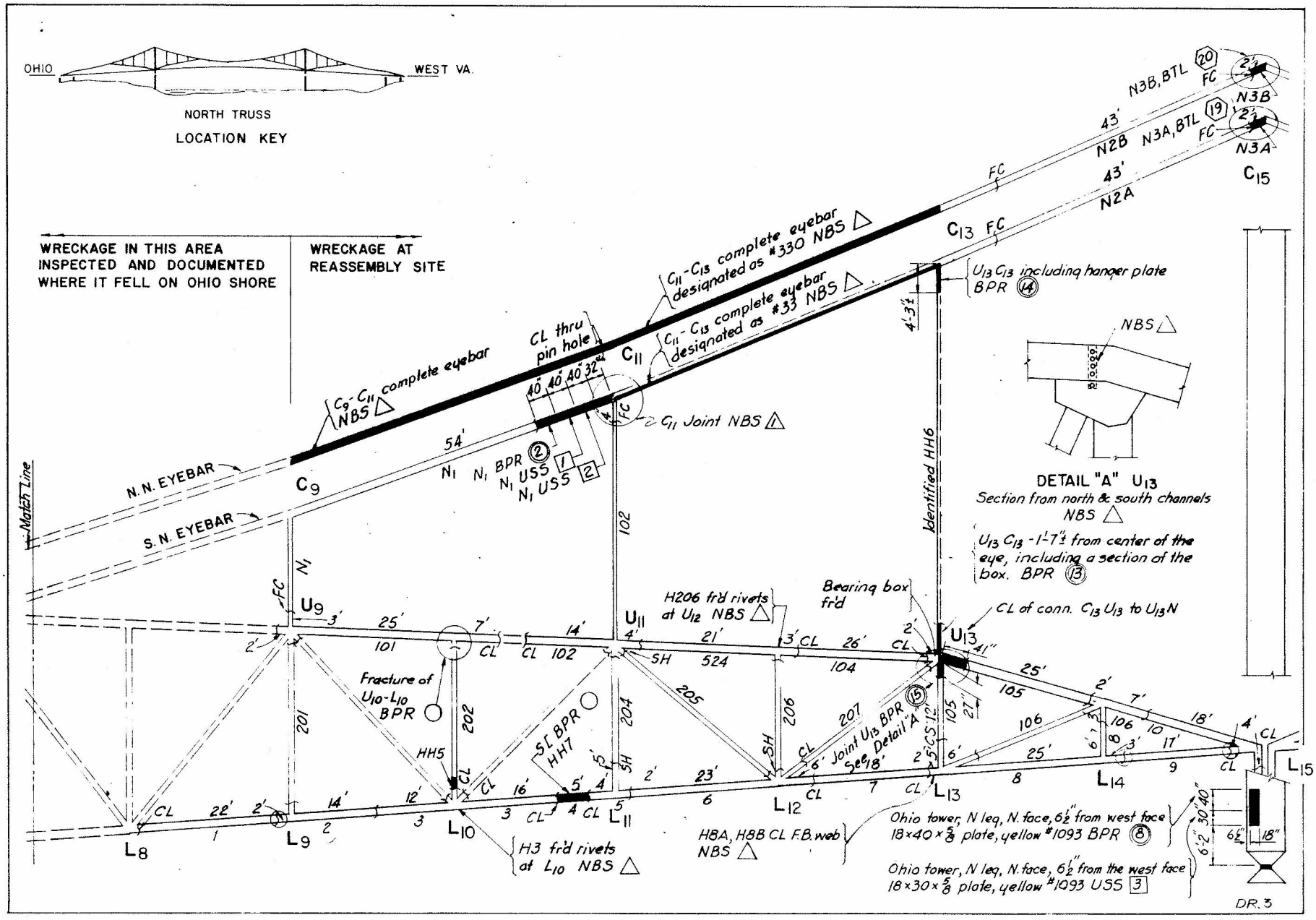
S. N. EYEBAR

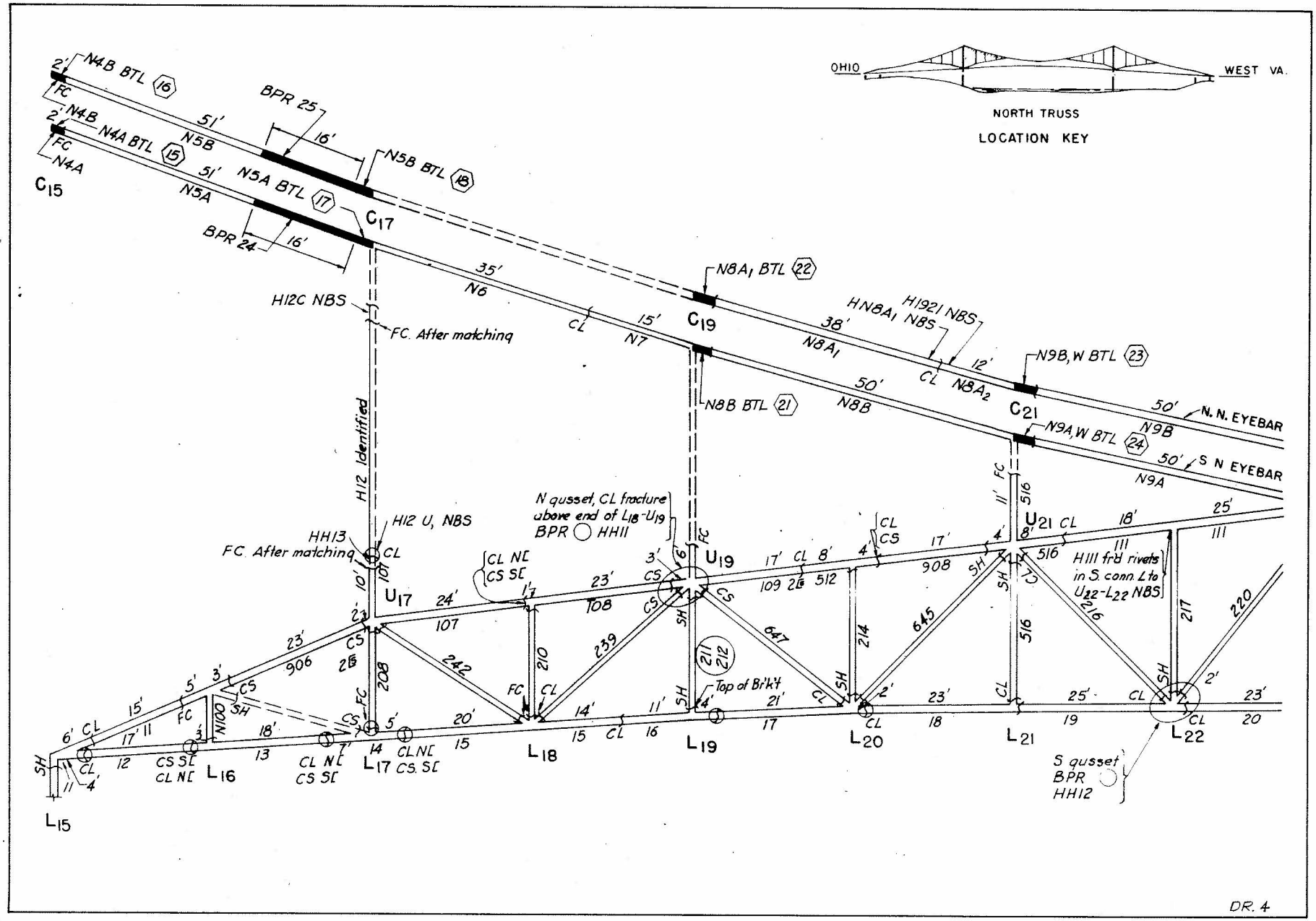
See Misc. samples

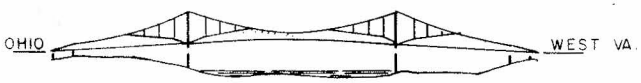
U_0 U_1 U_3 U_5 U_7

L_0 L_1 L_2 L_3 L_4 L_5 L_6 L_7

DR. 2

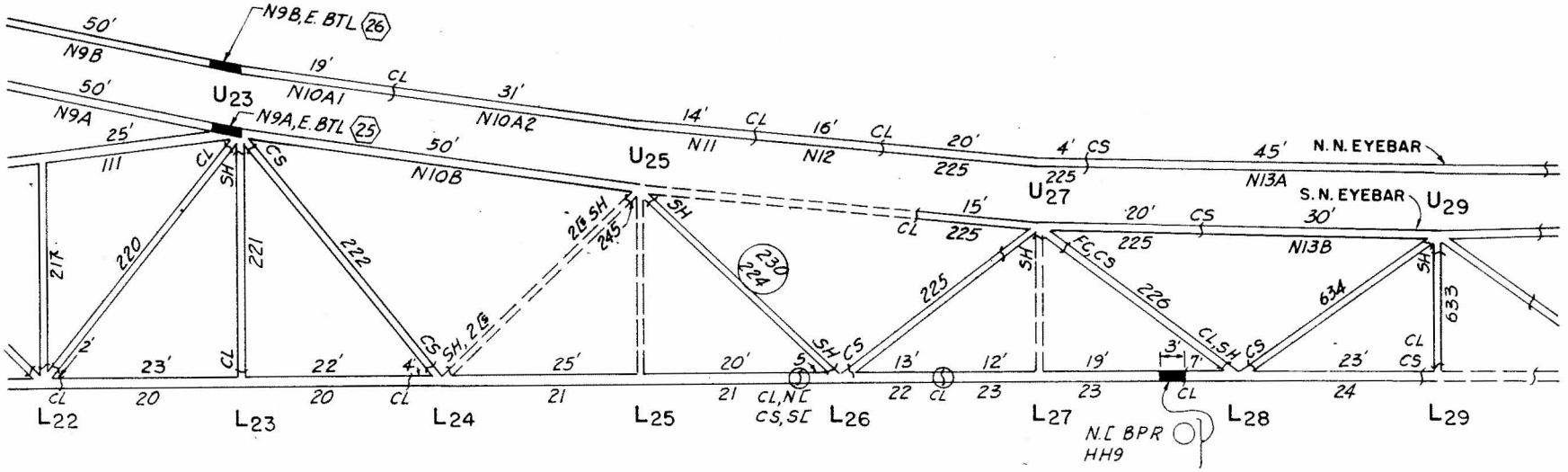

OHIO
WEST VA.
NORTH TRUSS
LOCATION KEY
WRECKAGE IN THIS AREA INSPECTED AND DOCUMENTED WHERE IT FELL ON OHIO SHORE
WRECKAGE AT REASSEMBLY SITE
N3B, BTL 20 FC N3B
N2B N3A, BTL 19 FC N3A
43'
43'
N2A
C15
C13 FC
C11 - C13 complete eyebar designated as #330 NBS
C11 - C13 complete eyebar designated as #33 NBS
U13 C13 including hanger plate BPR 14
4'-3½"
C9 - C11 complete eyebar NBS
CL thru pin hole
40" 40" 40" 32"
C11
FC
C11 Joint NBS
54'
N1 N1 BPR 2
N1 USS 1
N1 USS 2
N.N. EYEBAR
S.N. EYEBAR
C9
Identified HH6
102
N1
FC
U9
3'
25'
7'
14'
U11
4'
21'
3' CL
26'
CL
2'
U13
41"
101
CL
CL 102
SH
524
104
H206 frd rivets at U12 NBS
Bearing box frd
CL of conn. C13 U13 to U13N
Fracture of U10-L10 BPR
201
202
HH5
SL BPR
HH7
204
205
206
207
SH
CL
Joint U13 BPR 15 See Detail "A" 18'
2'-5" CS 12"
105
27'
25'
105
2'
7'
18'
4'
CL
106
106
6'-3"
8
3'
10
17'
CL
L15
L8
L9
L10
L11
L12
L13
L14
CL 22' 2' 14' 12' CL 16' 5' 4' CL 2' 23' 6 CL 7 CL 8 9 CL
1 2 3 3 CL 4 CL 5
H3 frd rivets at L10 NBS
H8A, H8B CL F.B. web NBS
Ohio tower, N leg, N. face, 6½" from west face 18×40×⅝ plate, yellow #1093 BPR 8
Ohio tower, N leg, N. face, 6½" from the west face 18×30×⅝ plate, yellow #1093 USS 3
6'-2" 30.40"
6½"
18"
DETAIL "A" U13
Section from north & south channels NBS
U13 C13 - 1'-7½" from center of the eye, including a section of the box. BPR 13
NBS
DR. 3


OHIO
WEST VA.
NORTH TRUSS
LOCATION KEY
N4B BTL 16
N4A BTL 15
N5B BTL 18
N5A BTL 17
BPR 25
BPR 24
C15
C17
C19
C21
N8A1 BTL 22
N8B BTL 21
N9B, W BTL 23
N9A, W BTL 24
N. N. EYEBAR
S N EYEBAR
H12C NBS
FC. After matching
H12 identified
HH13
H12 U, NBS
N qusset, CL fracture above end of L18-U19 BPR HH11
H1921 NBS
H N8A1 NBS
H111 frd rivets in S. conn. L to U22-L22 NBS
Top of Br'kY
S qusset BPR HH12
U17
U19
U21 CL
L15
L16
L17 CS. SE
L18
L19
L20
L21
L22
DR. 4



NORTH TRUSS

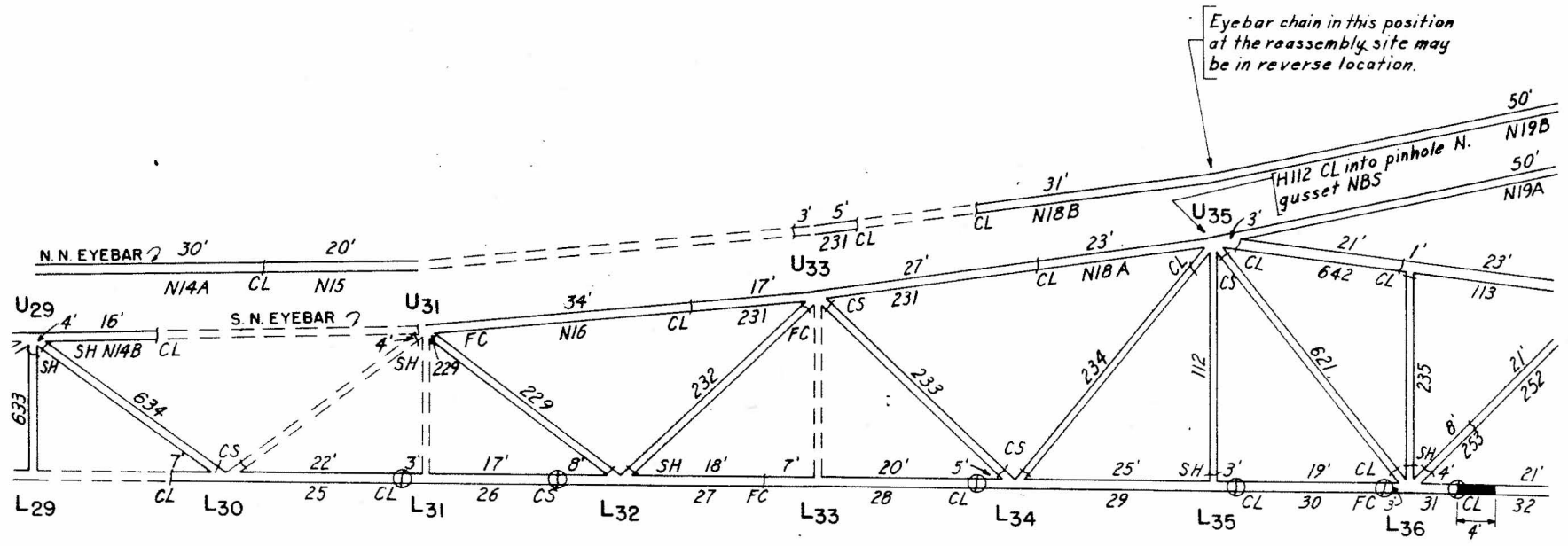
LOCATION KEY



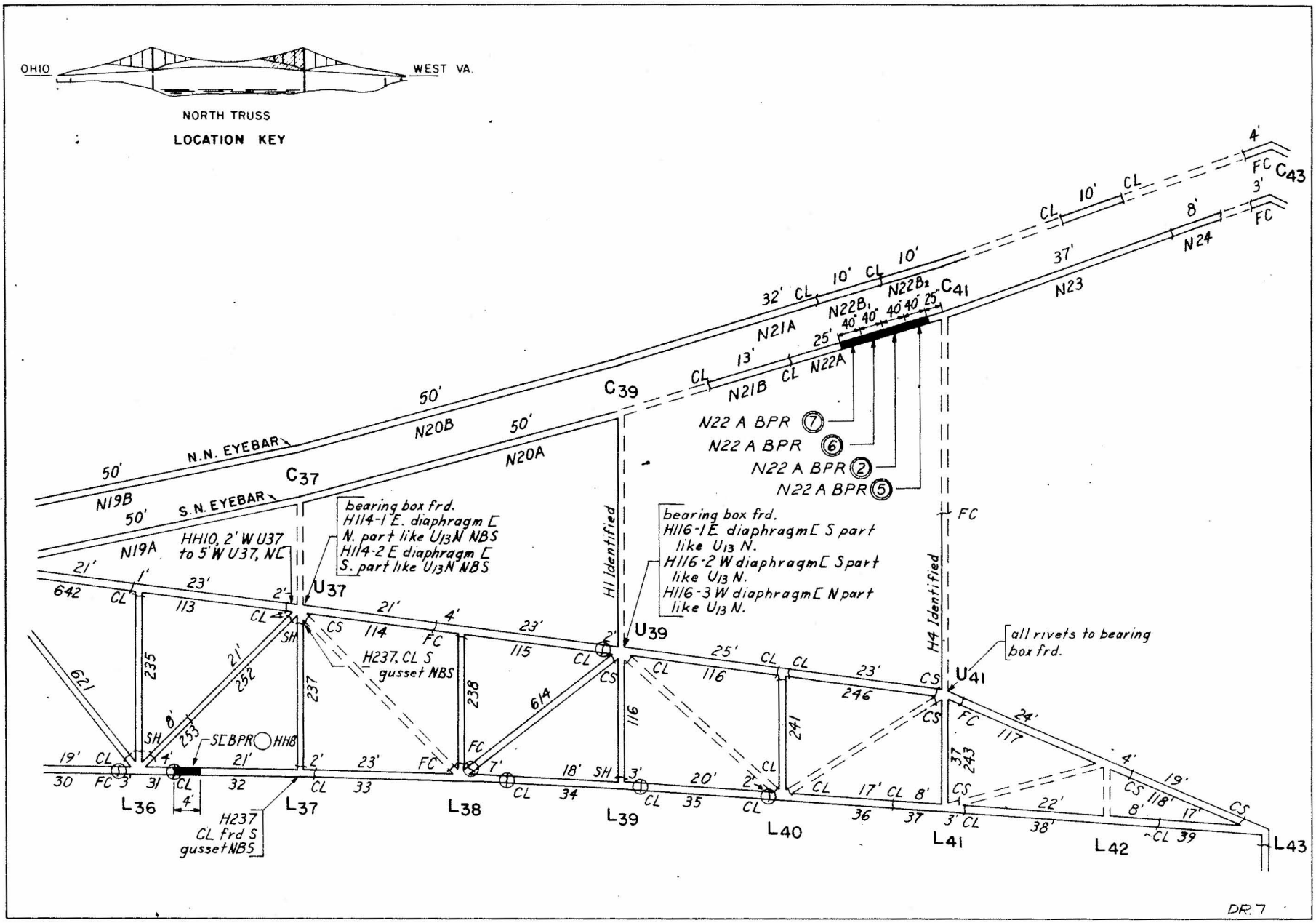
DR. 5

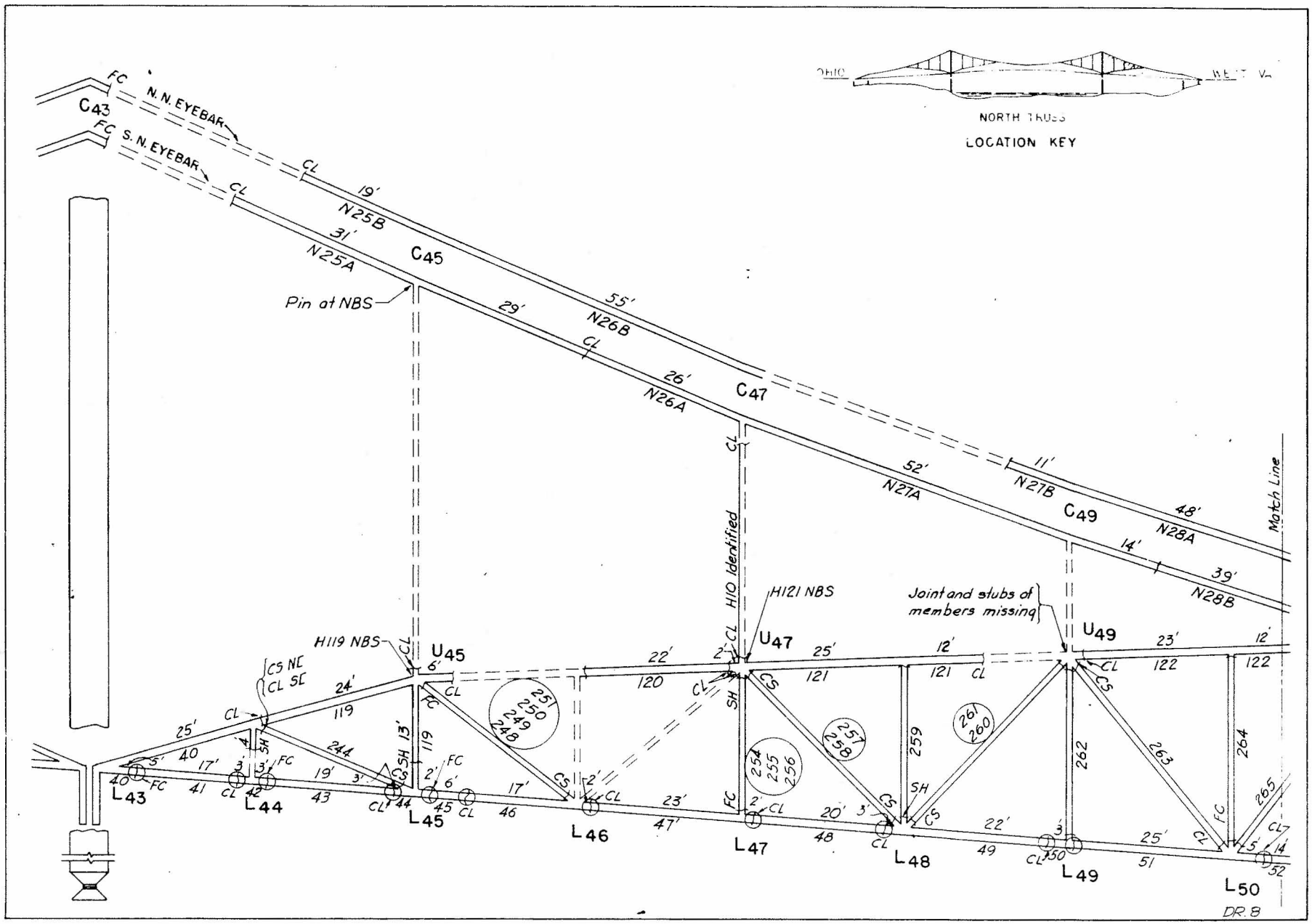
NORTH TRUSS

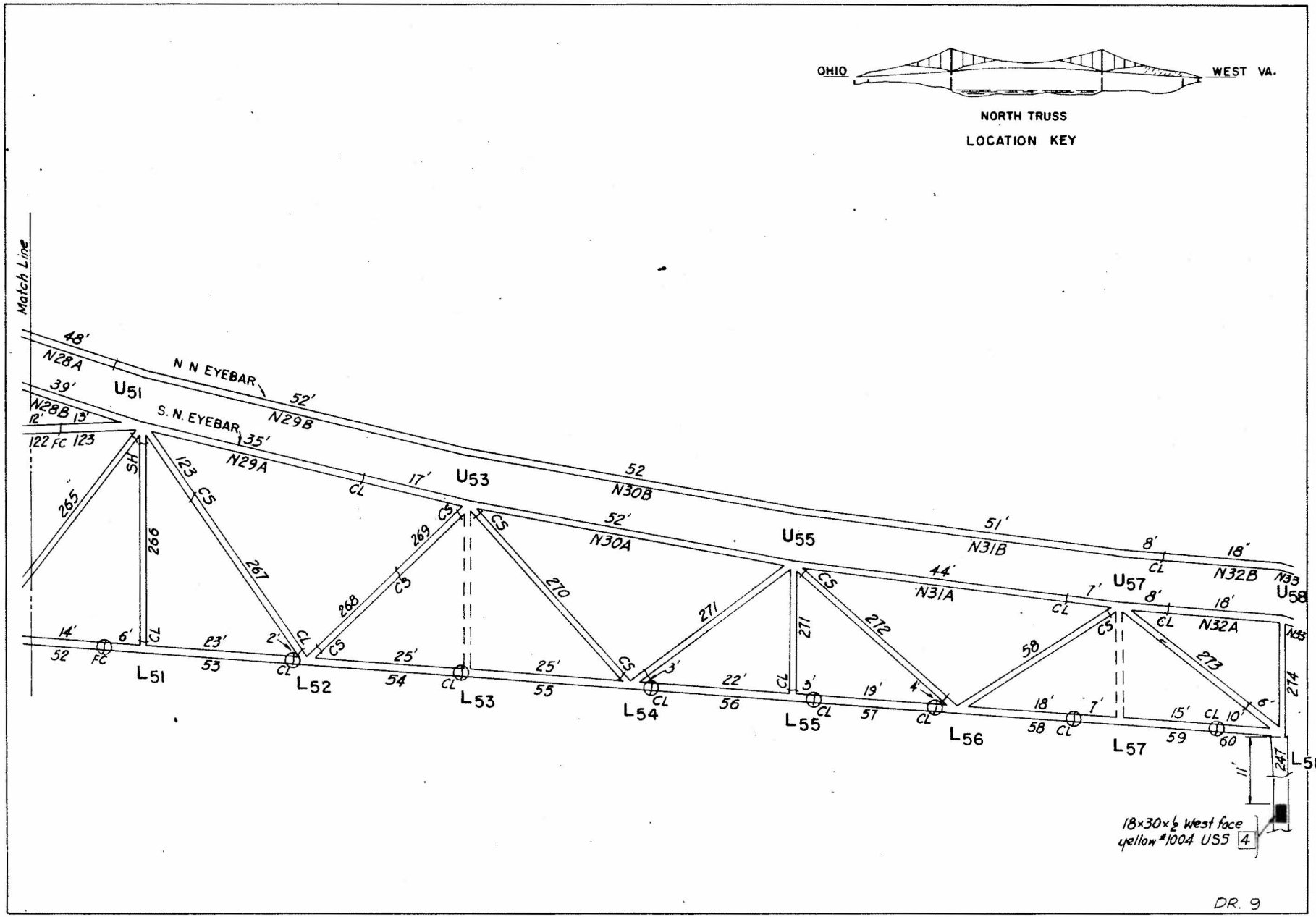
LOCATION KEY



DR. 6


OHIO
WEST VA.
NORTH TRUSS
LOCATION KEY
N.N. EYEBAR
S.N. EYEBAR
N19B
N19A
N20B
N20A
N21A
N21B
N22A
N22B1
N22B2
N23
N24
C37
C39
C41
C43
U37
U39
U41
L36
L37
L38
L39
L40
L41
L42
L43
HH10, 2' W U37 to 5' W U37, NC
bearing box frd. H114-1 E. diaphragm C N. part like U13N NBS H114-2 E diaphragm C S. part like U13N NBS
bearing box frd. H116-1 E diaphragm C S part like U13 N. H116-2 W diaphragm C S part like U13 N. H116-3 W diaphragm C N part like U13 N.
H1 Identified
H4 Identified
N22 A BPR (7)
N22 A BPR (6)
N22 A BPR (2)
N22 A BPR (5)
all rivets to bearing box frd.
H237, CL S gusset NBS
H237 CL frd S gusset NBS
SE BPR HH8
DR. 7


OHIO
WEST VA.
NORTH TRUSS
LOCATION KEY
C43
FC N. N. EYEBAR
FC S. N. EYEBAR
CL
19'
N25B
31'
N25A
C45
Pin at NBS
29'
N26B
26'
N26A
C47
55'
52'
N27A
11'
N27B
C49
48'
N28A
14'
39'
N28B
Match Line
H10 Identified
H121 NBS
Joint and stubs of members missing
H119 NBS
U45
U47
U49
CS NL
CL SL
24'
25'
40'
17'
19'
22'
25'
12'
23'
120
121
122
119
244
SH
FC
CS
SL
6'
2'
3'
5'
251
250
249
248
254
255
256
257
258
259
261
260
262
263
264
265
L43
L44
L45
L46
L47
L48
L49
L50
40
41
42
43
44
45
46
47
48
49
50
51
52
DR. 8


OHIO
WEST VA.
NORTH TRUSS
LOCATION KEY
Match Line
48'
N28A
N N EYEBAR
52'
N29B
39'
N28B
S. N. EYEBAR
35'
N29A
U51
U53
U55
U57
U58
52
N30B
52'
N30A
51'
N31B
44'
N31A
8'
18'
N32B
N33
N32A
122 FC 123
265
SH
266
123
CS
267
CL
17'
269
268
270
271
272
273
274
50
14'
6'
23'
2'
25'
25'
3'
22'
3'
19'
4'
18'
7'
15'
CL
10'
8'
52
FC
53
54
55
56
57
58
59
60
L51
L52
L53
L54
L55
L56
L57
L58
247
18×30×½ West face
yellow #1004 USS
4
DR. 9

SOUTH TRUSS

LOCATION KEY

WRECKAGE IN THIS AREA
INSPECTED AND DOCUMENTED
WHERE IT FELL ON OHIO SHORE

Match Line

S. S. EYEBAR

N. S. EYEBAR

HH3 S. gusset Pl. of U_3 BPR
HH2 N. gusset Pl. of U_3 BPR

15'

15'

BPR 21

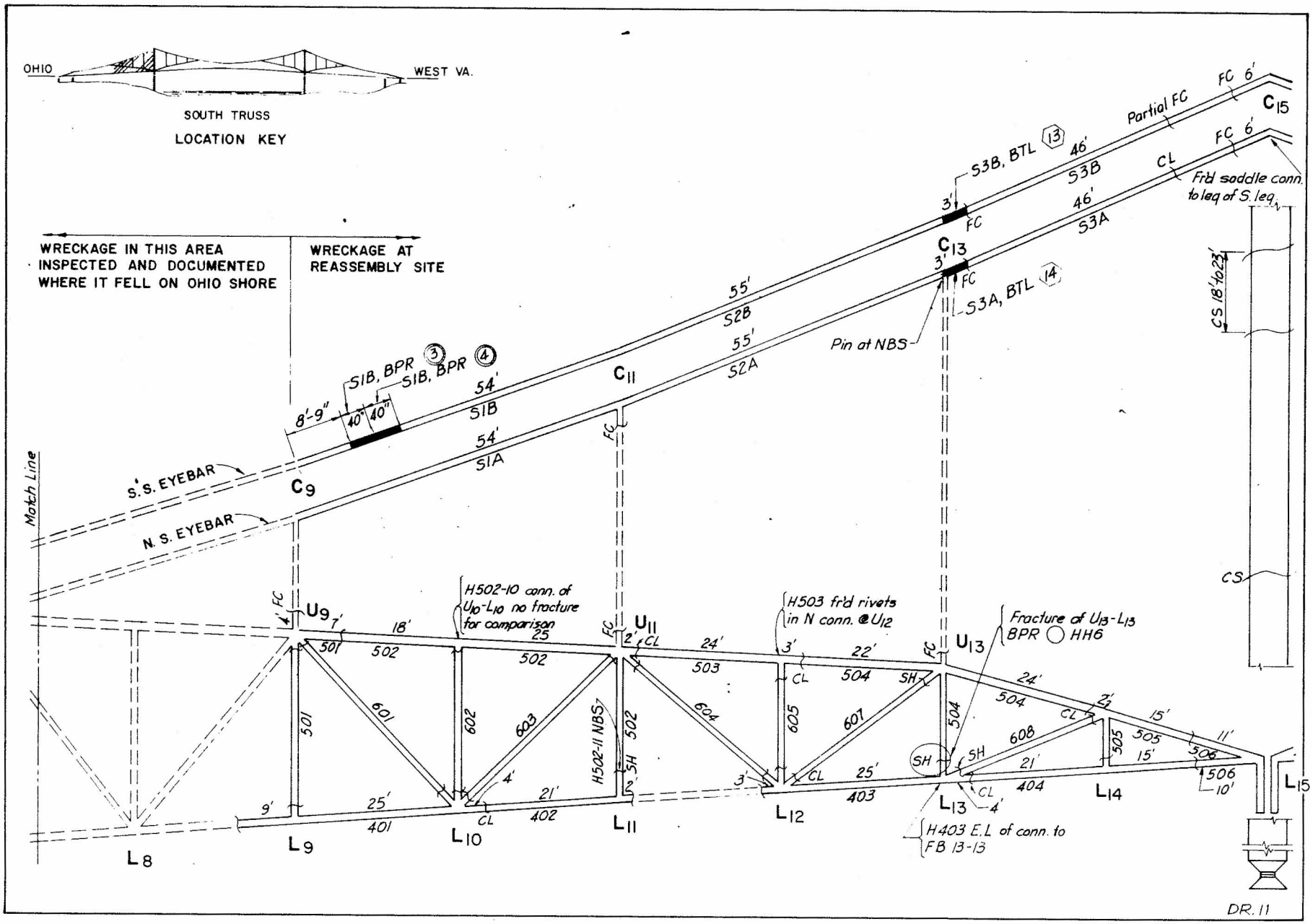
BPR 20

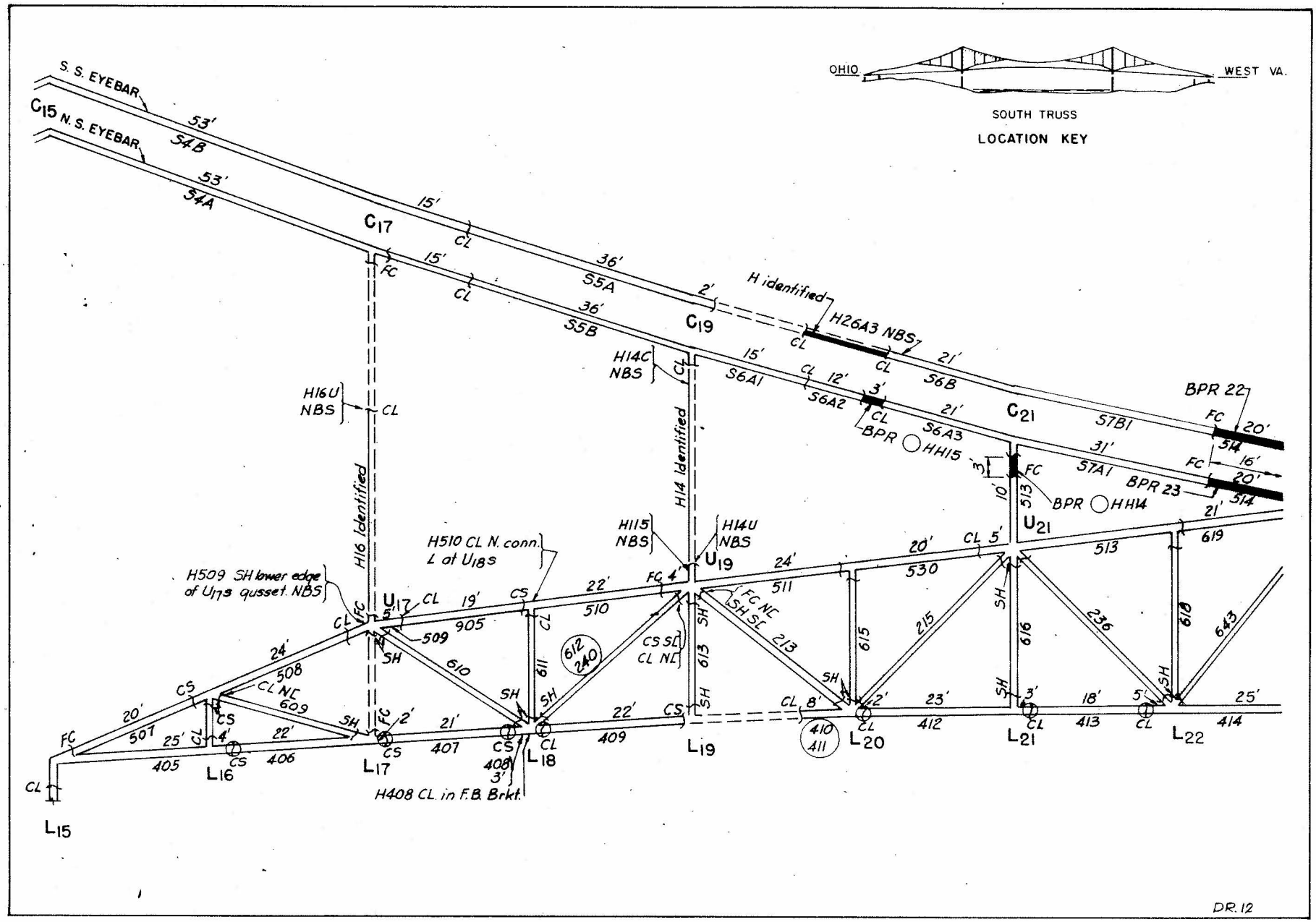
Gusset Pl. U_5 S. N. Pl.
BPR ○ HH1

U_0 U_1 U_3 U_5 U_7

L_0 L_1 L_2 L_3 L_4 L_5 L_6 L_7

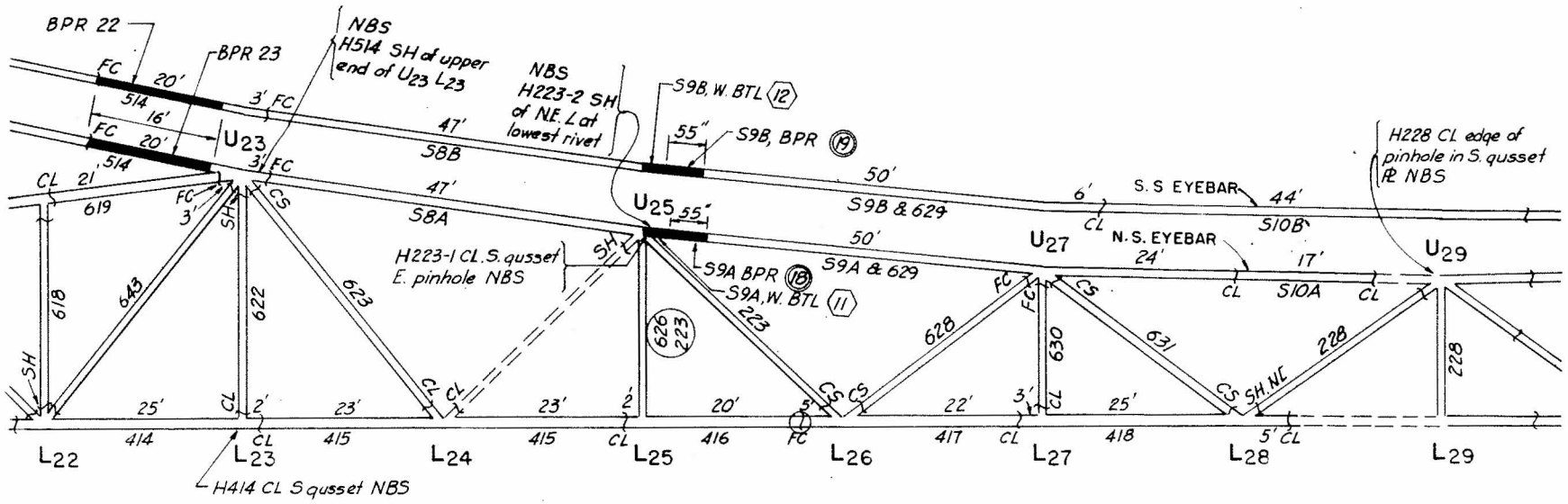
DR. 10


OHIO
WEST VA.
SOUTH TRUSS
LOCATION KEY
WRECKAGE IN THIS AREA INSPECTED AND DOCUMENTED WHERE IT FELL ON OHIO SHORE
WRECKAGE AT REASSEMBLY SITE
Match Line
S. S. EYEBAR
N. S. EYEBAR
C9
C11
C13
C15
U9
U11
U13
L8
L9
L10
L11
L12
L13
L14
L15
S1B, BPR 3
S1B, BPR 4
8'-9"
40"
40"
54'
S1B
54'
S1A
55'
S2B
55'
S2A
S3B, BTL 13
46'
S3B
S3A, BTL 14
46'
S3A
Partial FC
FC 6'
FC 6'
Frld saddle conn. to leg of S. leg
CL
3'
FC
Pin at NBS
CS 18'10 23'
CS
H502-10 conn. of U10-L10 no fracture for comparison
H503 frld rivets in N conn. @ U12
Fracture of U13-L13 BPR ○ HH6
H502-11 NBS
SH
H403 E.L of conn. to FB 13-13
DR. 11


OHIO
WEST VA.
SOUTH TRUSS
LOCATION KEY
S. S. EYEBAR
N. S. EYEBAR
C15
C17
C19
C21
U17
U19
U21
L15
L16
L17
L18
L19
L20
L21
L22
S4B
S4A
S5A
S5B
S6A1
S6A2
S6A3
S6B
S7A1
S7B1
H identified
H26A3 NBS
H16U NBS
H16 identified
H14C NBS
H14 identified
H115 NBS
H14U NBS
H510 CL N. conn. L at U18S
H509 SH lower edge of U17S gusset. NBS
BPR 22
BPR 23
BPR HH15
BPR HH14
H408 CL in F.B. Brkt.
DR. 12

SOUTH TRUSS

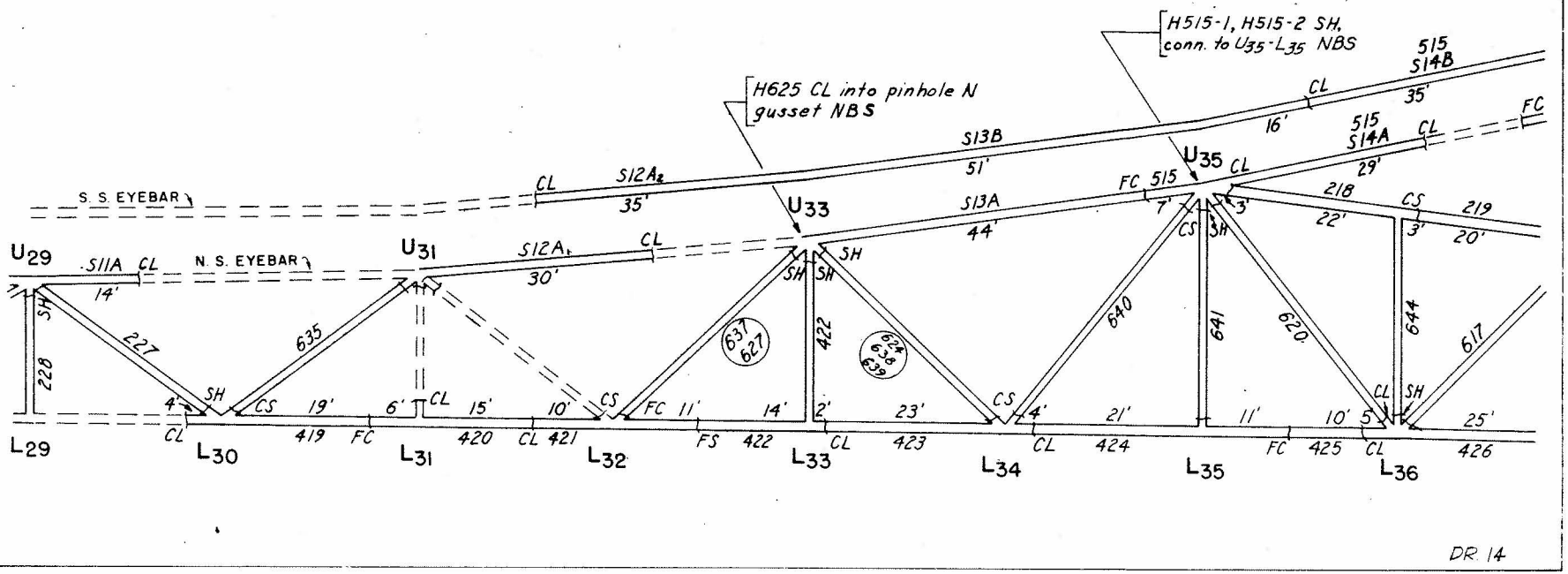
LOCATION KEY



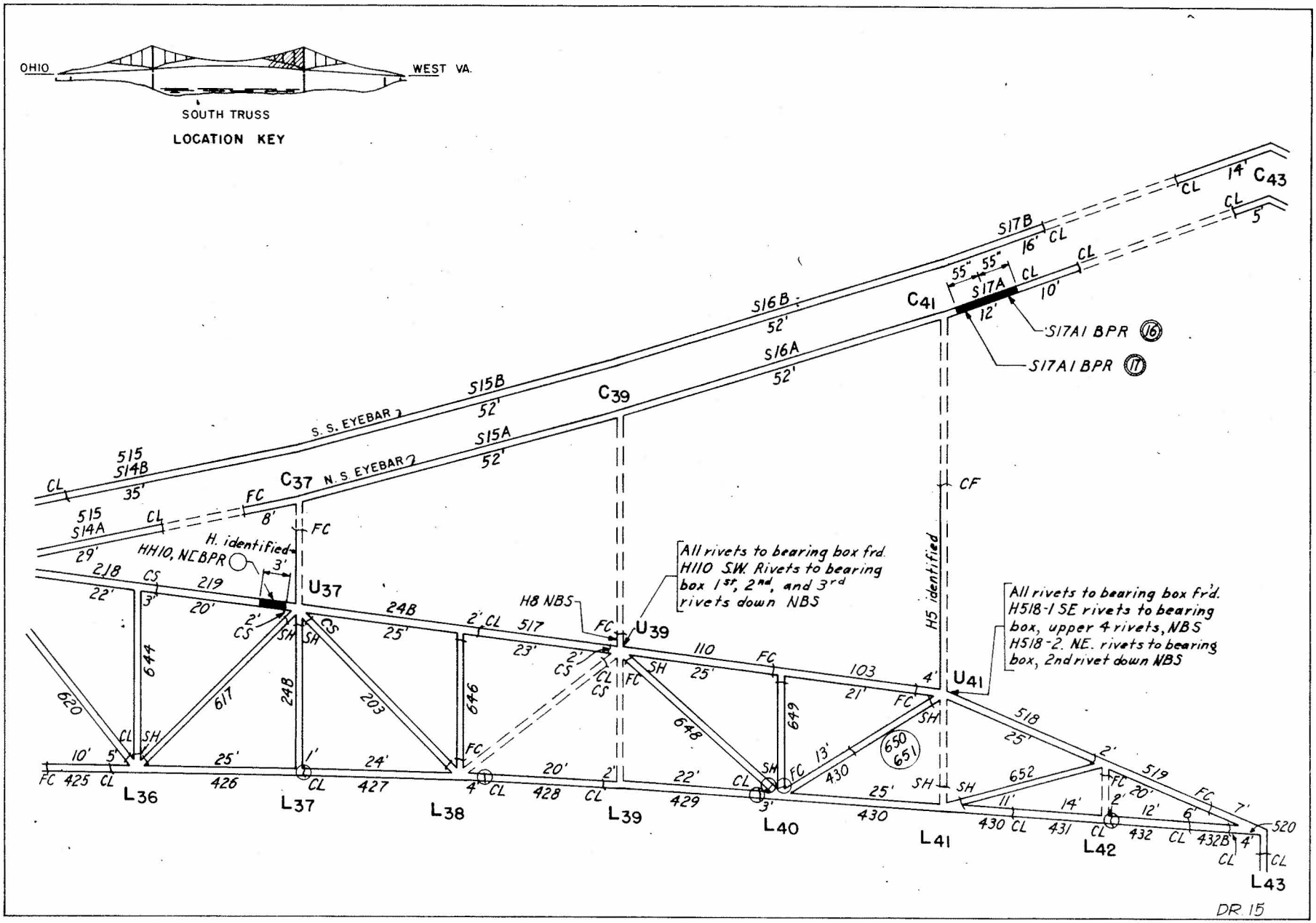
DR. 13

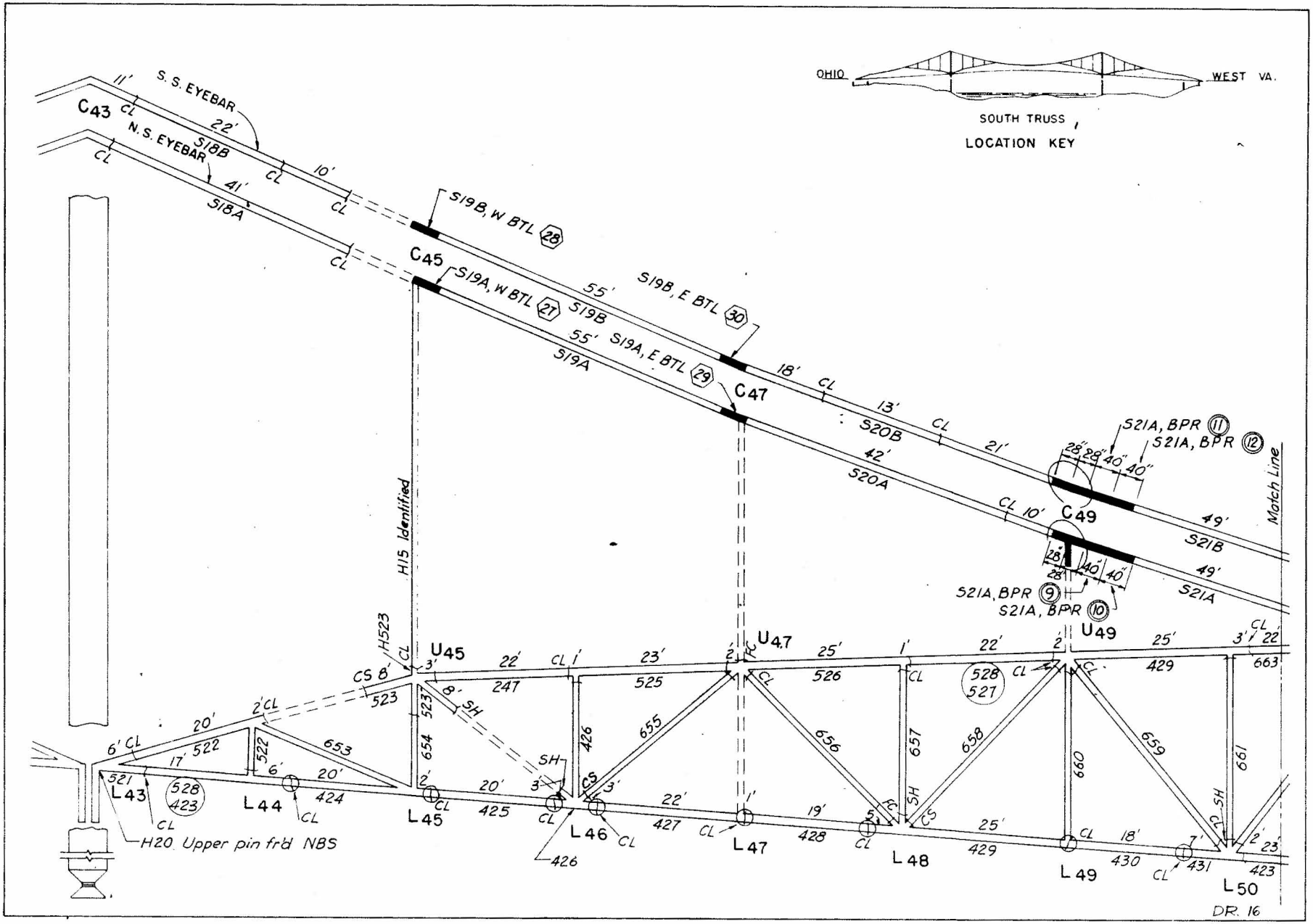
SOUTH TRUSS

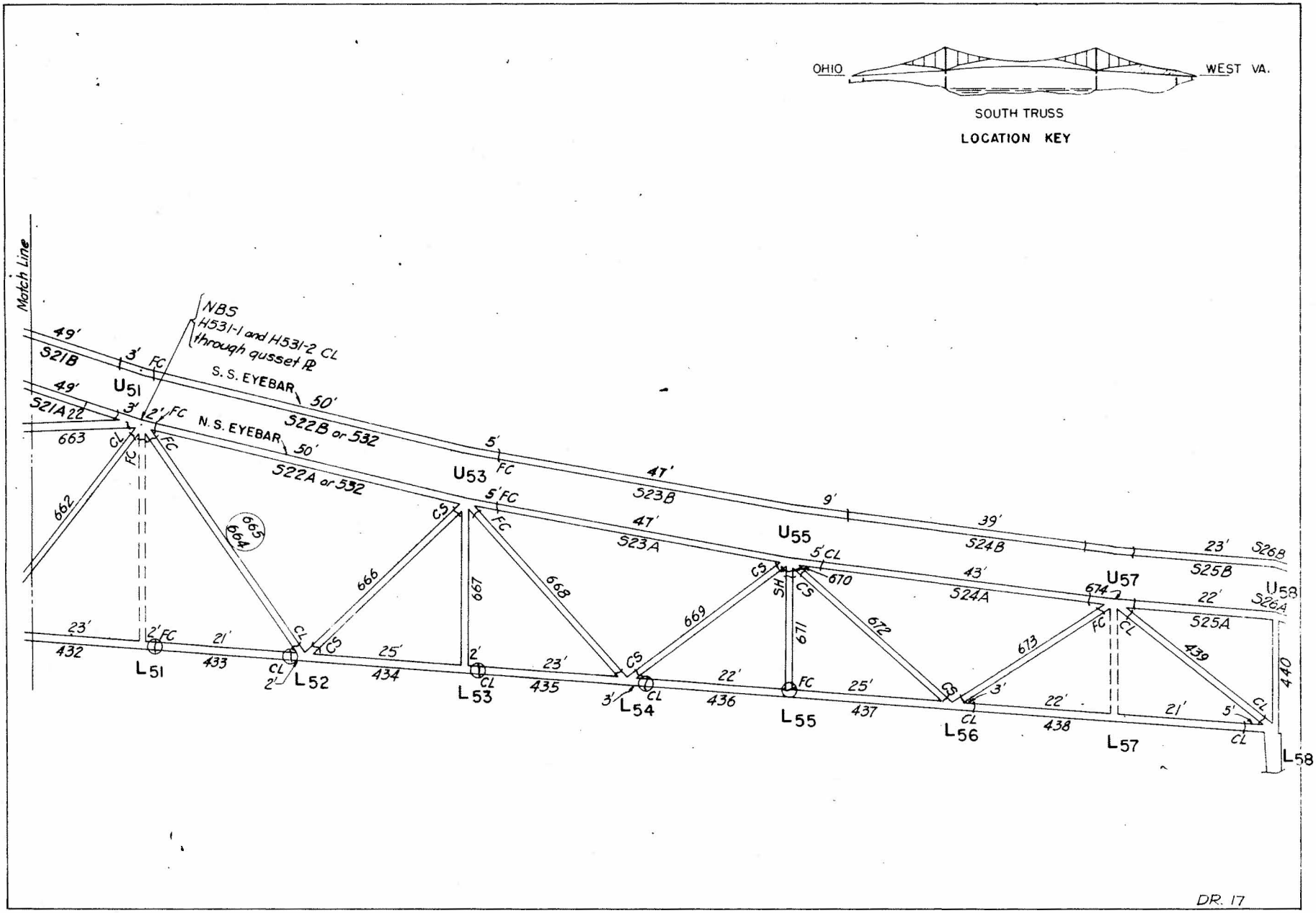
LOCATION KEY



DR. 14


OHIO
WEST VA.
SOUTH TRUSS
LOCATION KEY
S. S. EYEBAR
N. S EYEBAR
S17B
S16B
S15B
S14B
S17A
S16A
S15A
S14A
515
C37
C39
C41
C43
U37
U39
U41
L36
L37
L38
L39
L40
L41
L42
L43
S17A1 BPR (16)
S17A1 BPR (17)
H. identified
HH10, NEBPR
H8 NBS
All rivets to bearing box frd. H110 SW. Rivets to bearing box 1st, 2nd, and 3rd rivets down NBS
H5 identified
All rivets to bearing box frd. H518-1 SE rivets to bearing box, upper 4 rivets, NBS
H518-2. NE. rivets to bearing box, 2nd rivet down NBS
DR 15


OHIO
WEST VA.
SOUTH TRUSS
LOCATION KEY
C43
C45
C47
C49
S. S. EYEBAR
N. S. EYEBAR
S18B
S18A
S19B, W BTL 28
S19A, W BTL 27
S19B, E BTL 30
S19A, E BTL 29
S19B
S19A
S20B
S20A
S21A, BPR 11
S21A, BPR 12
S21A, BPR 9
S21A, BPR 10
S21B
S21A
Match Line
H15 Identified
H523
U45
U47
U49
L43
L44
L45
L46
L47
L48
L49
L50
H20 Upper pin frd NBS
DR. 16


OHIO
WEST VA.
SOUTH TRUSS
LOCATION KEY
Match Line
NBS
H531-1 and H531-2 CL through gusset PL
S. S. EYEBAR
N. S. EYEBAR
U51
U53
U55
U57
U58
L51
L52
L53
L54
L55
L56
L57
L58
521B
521A
522B or 532
522A or 532
523B
523A
524B
524A
525B
525A
526B
526A
DR. 17