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FINAL REPORT

LIABILITY AND TRAFFIC CONTROL CONSIDERATIONS FOR LOW WATER STREAM CROSSINGS

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

The current shortage of highway funds precludes the immediate replacement of most of the bridges that have been evaluated as structurally deficient or functionally obsolete or both. A low water stream crossing (LWSC) affords an economical alternative to the replacement of a bridge with another bridge in many instances. However, the potential liability that might be incurred from the use of LWSCs has served as a deterrent to their use. Nor have guidelines for traffic control devices been developed for specific application to LWSCs. This research addressed the problems of liability and traffic control associated with the use of LWSCs.

Input to the findings from this research was provided by several persons contacted by telephone plus 189 persons who responded to a questionnaire concerning their experience with LWSCs. It was concluded from this research that a significant potential for accidents and liability claims could result from the use of LWSCs. However, it was also concluded that this liability could be reduced to within acceptable limits if adequate warning of the presence of an LWSC were afforded to road users. The potential for accidents and liability could further be reduced if vehicular passage over an LWSC were precluded during periods when the road was flooded. Under these conditions, it is believed, the potential for liability from the use of an LWSC on an unpaved, rural road would be even less than that resulting from the continuing use of an inadequate bridge.

The signs recommended for use in advance of an LWSC include two warning signs and one regulatory sign with legends as follows:

FLOOD AREA AHEAD

IMPASSABLE DURING HIGH WATER

DO NOT ENTER WHEN FLOODED

Use of the regulatory sign would require an appropriate resolution by the Board of Supervisors having responsibility for a county road.

Other recommendations include the optional use of either a supplemental distance advisory plate or an advisory speed plate, or both, under circumstances where these may be needed. It was also recommended that LWSCs be used only on unpaved roads and that they not be used in locations where flooding of an LWSC would deprive dwelling places of emergency ground access.

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGMENTS

The research reported here was sponsored by the Iowa Highway Research Board and was carried out by the Engineering Research Institute, Iowa State University. Financial support was afforded by the Iowa Department of Transportation.

Research personnel wish to extend their gratitude to the approximately 275 persons in states other than Iowa who assisted this research effort by sharing their time and knowledge either by communicating with us by telephone or letter or by completing and returning a questionnaire regarding low water stream crossings. We are also indebted to those who participated in our evaluation of signing. The Advisory Panel that worked with the research staff throughout the progress of the research was especially helpful. Members of this panel were:

Phil Dvorak, P.E., Grundy County Engineer

George Hanzlik, P.E., Winneshiek County Engineer

Richard Henely, P.E., formerly Kossuth County Engineer

Carl Schnoor, P.E., Boone County Engineer

Dale Wight, P.E., Crawford County Engineer

Invaluable support and assistance was also received from Steven Tritsch, Secondary Road Research Coordinator, Highway Division, Iowa Department of Transportation.

Despite the substantial assistance from others, however, the interpretations of factual input to the research, opinions, findings, and conclusions are those of the authors and are not necessarily shared by others.

I. INTRODUCTION

Background for the Study

Virtually every governmental entity responsible for a highway system currently is facing a disparity of unprecedented magnitude between fiscal needs and available funds, with needs far greater than the funds available. The result of this disparity is that improvements are being deferred that would have seemed routine in the recent past when needs and resources were reasonably in balance. Among the deferred improvements in Iowa are replacements for hundreds of bridges that have been assessed as being structurally deficient or functionally obsolete or both. The extremely high costs of new bridges when combined with the current revenue shortfall suggests that many unsuitable bridges will not be replaced in the foreseeable future.

One alternative to the replacement of an old bridge with a new bridge that offers substantial economic advantages is to replace a bridge with a low water stream crossing (LWSC). An LWSC, as defined here, is a ford, vented ford (one having some number of culvert pipes), low water bridge, or other structure that is designed so that its hydraulic capacity will be insufficient one or more times during a year of normal rainfall. This design concept is in contrast to the more usual practice of designing for a flood that may occur only once every 20 years or more.

An economical method of carrying highways across small watercourses would permit highway authorities to make better use of the resources available for highway improvments. In turn, this would

result in an improvement in the quality of highway service and safety. LWSCs are used extensively in some states and to a limited extent in most states, including Iowa. Mitigating against their further use in Iowa is concern for the potential costs of litigation and damage awards if their use were not to be received favorably by the public. Another concern that has been expressed is that there is no generally accepted system of traffic control that has been associated with use of LWSCs. These two related concerns afforded the incentive for this research.

As far as is known, no previous research has addressed the issues of liability and traffic control considerations for LWSCs. A research project sponsored by the Federal Highway Administration was initiated in 1979 to investigate the "Design and Construction of Low-Water Stream Crossings." Although this research is to develop decision criteria that are to assist in selecting types of crossings, the problem of liability is not specifically addressed. Nor does the scope of the research include traffic control considerations.

Project Overview

Research Goal and Objectives

The goal of the research was to assess the practicality of LWSCs for use on low volume roads in Iowa. Such assessment was to be in terms of the capability of responsible highway agencies to provide suitable traffic control at such crossings as well as to preclude the likelihood of claims for tort liability that would offset the anticipated cost effectiveness of LWSCs.

One objective of the research was to afford persons responsible for the planning, design, construction, and maintenance of the highway system with an evaluation of the potential tort liability associated with the provision of stream crossings of such nature that the road surface will be flooded one or more times during a year of normal rainfall. Another objective was to provide guidance for the selection of traffic control measures and devices that will minimize the hazard involved in the use of such stream crossings.

The anticipated benefit from this research will be to permit the use of more cost effective drainage structures that are suitable for low volume roads without an increase in hazard to motorists. Their use, by reducing the proportion of highway construction and maintenance resources required for stream crossing structures, can be expected to make more resources available for other necessary highway improvements with a concomitant beneficial effect on highway safety.

Research Approach

The technical literature was reviewed for publications that addressed the issues of liability and traffic control for LWSCs. Except for one article, this subject apparently had not been covered.*

In respect to signing, other states were contacted to determine whether standards had been developed for use at LWSCs. No entirely suitable standard was located, although several states reported standard

*See Bingham, Joe M. "Design and Construction of Low Water Dips," Texas Highway Department Construction and Maintenance Bulletin No. 6 (May 1951), pp. 40-51. (Included in Compendium 4: Low Cost Water Crossings, Transportation Research Board.)

signs that subsequently were tested along with other signs reportedly used in association with LWSCs.

The primary input for the research was provided from persons in other states who have responsibility for highway systems including LWSCs. The process of developing a list of contact persons and receiving the benefit of their experience is described in Chapter II of this report.

An evaluation of the many different signs and signing patterns used by highway agencies having LWSCs is included in Chapter III. This evaluation led to the selection of specific signs recommended for use in association with LWSCs.

The conclusions and recommendations resulting from this research are presented in Chapter IV. Recommendations, prior to their inclusion in this report, were reviewed by the Advisory Panel that assisted the research team. Suggestions received from members of the Advisory Panel have been incorporated in the recommendations.

II. SURVEY OF EXPERIENCE WITH LOW WATER STREAM CROSSINGS

Most highway officials in Iowa have had little or no experience with low water stream crossings (LWSCs). However, their use reportedly is quite extensive in some other states. Consequently, a questionnaire was designed to obtain information from persons in other states who are or have been responsible for road systems that include LWSCs. (A copy of the questionnaire is included as Appendix A to this report.) Telephone contacts were made with persons in 44 states other than Iowa, plus the District of Columbia, in order to develop a list of persons who could be expected to provide meaningful responses to the questionnaire. Contact with Alaska was made by mail, and no contact was undertaken with Connecticut, Hawaii, New Jersey, or Rhode Island. Telephone contacts were completed as follows:

State highway officials	50
Local highway officials	10
County associations	3
Federal employees	5
Others	4
Total	72

Responses to these telephone contacts varied. Officials in some states disclaimed any knowledge of use of LWSCs within their state. In a few cases, the use of LWSCs was acknowledged but there reportedly were no officials bearing responsibility for them who could reasonably be expected to respond to an inquiry about their use. Some persons contacted supplied information verbally and expressed the opinion that no

further information could be made available. Other states furnished extensive lists of persons, primarily county engineers or road supervisors, who have had significant experience with LWSCs. In all, a list of 249 persons in 25 states was developed as a result of the telephone contacts.

Questionnaire recipients were furnished a list of other persons in their state who received questionnaires and were asked to suggest additional persons with knowledge of the use of LWSCs. This request generated 39 additional names in 13 states.

No list of persons with specific experience with LWSCs was furnished from Oklahoma. However, the Executive Secretary of the Association of County Commissioners of Oklahoma suggested that each County Commissioner, 231 persons in 77 counties, should be contacted. Each of these Commissioners received a questionnaire with a letter of transmittal that differed from the letter sent to those in other states (also shown in Appendix A).

Thus a total of 519 questionnaires was sent to persons in 26 states. Of these, 154 responses were received from 288 recipients in 23 states, a response rate of 53.5 percent. Of the 231 County Commissioners in Oklahoma, 35 completed questionnaires were returned, a response rate of 15.2 percent. The number of responses from each state is displayed in Table 1.

Several respondents included photographs or design drawings of actual LWSCs or traffic control devices. Information on standards for traffic control devices was also received separately from seven states.

Table 1. Number of questionnaire responses per state.

State	Number of Responses
Alabama	4
Arizona	7
Arkansas	4
California	3
Colorado	12
Delaware	2
Idaho	5
Illinois	19
Indiana	1
Kansas	16
Kentucky	3
Michigan	1
Minnesota	5
Missouri	17
Montana	2
Nevada	4
New Mexico	1
North Dakota	5
Oklahoma	35
South Dakota	2
Texas	19
Utah	5
Virginia	3
Wisconsin	14
Total	189

Extent of Usage of LWSCs

Of those who responded to the survey, 56 disclaimed any experience with LWSCs. Use of LWSCs by 132 of the other 133 respondents was reported as follows:

	Number	Percent
Ford or dip	85	64
Vented ford	67	51
Low water bridge	60	45
Other LWSCs	14	11

About 54 percent of the respondents reported use of more than one type of LWSC. The number of LWSCs reported per jurisdiction (generally a county) varied from 1 to 625 with an average of 27 and a median value of 12.

A majority (61 percent) of those using LWSCs reported using them only on unpaved roads. However, they were used only on paved roads in 12 percent and on both types of roads in 27 percent of the reporting jurisdictions.

Claims Experience

Only nine respondents, 7 percent of those responding to this question, reported any actual experience with claims submitted against a governmental entity growing out of the use of LWSCs. However, other respondents, as well as some of the persons contacted by telephone, reported accidents, some resulting in fatalities, that would probably have resulted in a tort claim if the accident had occurred in a state

not enjoying sovereign immunity. Dollar amounts were not known by all of the respondents, but the amounts reported ranged up to $1,000,000 in one county in Arizona. A vehicle that was washed away while trying to negotiate a flooded LWSC was the problem reported most frequently that resulted in tort claims. The next most troublesome problem was that resulting from erosion of the roadbed due to its being flooded. Other problems reported included road roughness, the presence of dust from debris deposited on a roadway, and erosion of downstream farmland attributed to the use of an LWSC that had been flooded.

Use of Traffic Control Devices

The most frequent answer to the question "Do you have a standard method of signing at LWSCs?" was that there was no standard. This was the response from 48 percent of respondents to this question. Twenty-four percent reported usage according to a state standard and 28 percent used a locally developed standard. State standards, where they exist, appear not to be known or used by many of the persons responsible for LWSCs because there were only three states (a total of eight respondents) from which all respondents reported using signing according to a state standard. From eight other states, some respondents but not all reported use of a state standard.

Eighty-one percent of the respondents reported use of one or more warning signs to provide warning of an LWSC. Thirty-seven percent (representing 12 different states) reported use of a stream gage. Other responses to this question included use of hazard markers by

30 percent of the respondents, delineators by 29 percent, regulatory signs by 19 percent, and other devices by 14 percent.

It should be noted in this regard that some of the signs that were reported as warning signs carried a regulatory message. Some of the devices reported as warning signs deviated from the usual design of a warning sign by using a rectangular shape or a black message on a white background. Similar inconsistencies were noted among those devices reported as regulatory signs. The various warning and regulatory messages reportedly in use are noted in Table 2.

Informative Comments

Seventy-one respondents furnished additional comments concerning their experience with LWSCs. Several of these provided details on the design of LWSCs. Others indicated that they used LWSCs only on very low-volume roads, often with dirt surface, although some reported use only on gravel roads. The volume ranges mentioned included roads with an ADT of 1 or 2 vpd or roads used only by an individual rancher or for a mail route serving one or two patrons. One respondent from a state Department of Transportation indicated consideration of LWSCs on roads with volumes up to 75 vpd.

Suggestions or comments made by one or two respondents included the following:

- Use a speed advisory at LWSCs with a poor road surface.
- Add a speed limit sign if the dip is extreme.
- Design LWSCs so overtopping does not exceed a depth of 1 foot.

Table 2. Sign messages reported in use with LWSCs.

Warning Signs
CAUTION FLOOD AREA AHEAD
CAUTION FLOOD WATER
CAUTION WATER OVER ROAD DURING HEAVY RAINS
DANGER FLOOD AREA
DANGER LOW WATER CROSSING
DIP
DIP RIVER CROSSING
FLASH FLOOD AREA
FLOODED
HAZARDOUS DURING HEAVY RAIN
HAZARDOUS DURING HIGH WATER
HAZARDOUS WHEN WATER ACROSS ROAD
IMPASSABLE DURING HIGH WATER
LOW WATER CROSSING
LOW WATER CROSSING AHEAD
LOW WATER XING
POSSIBLE HIGH WATER
ROAD OVERFLOWS
ROADWAY SUBJECT TO FLOODING
SUBJECT TO FLOODING
WATCH FOR HIGH WATER
WATER CROSSING
Regulatory Signs
DO NOT CROSS DIP WHEN UNDER WATER
DO NOT DRIVE INTO WATER
DO NOT ENTER WHEN FLOODED
ROAD CLOSED WHEN FLOODED

- Curbs or bumper blocks trap trash.
- Signs are constantly vandalized.
- A vented ford was destroyed after the inlet end became plugged with debris.
- Maintenance is expensive because of debris collection and washouts.
- Flashing amber lights are used for warning.
- LWSCs are used to replace abandoned bridges.
- These installations are used as a last resort.
- Roads using LWSCs should be patrolled following rainfall and closed if flooded.
- LWSCs have been accepted very well.
- It is very important to inform drivers exactly what to expect ahead.
- Good engineering design can be accomplished with reasonable expense and still conform with safety guidelines as long as the public is warned by appropriate signs.

III. ANALYSIS OF SIGNING

Because the patterns of sign usage reported by survey respondents varied so widely, a most desirable signing pattern was not suggested. Therefore, further analysis was necessary before a specific pattern of sign usage could be recommended for use in association with LWSCs.

The research staff, in consultation with the Advisory Panel for this research, established criteria for the use of traffic control devices. These criteria were based largely on input from written comments and supplementary material submitted by survey respondents.

The most relevant comments from survey respondents were those pertaining to liability. From these, the research staff concluded that the potential liability from the use of LWSCs could be kept within tolerable limits only if drivers approaching an LWSC were afforded adequate warning of the existence of such a facility. Since most of the serious accidents and large claims that were reported resulted from the use of LWSCs during periods when LWSCs were actually flooded, it was also concluded that the potential for liability would be minimized if use of LWSCs was precluded while they were flooded. This suggested the possible use of a regulatory sign.

First Phase Evaluation

Accordingly, a three-phase evaluation process was undertaken. In the first phase, a limited number (13) of knowledgeable persons were asked to evaluate five different signing systems, 20 specific warning sign messages, and four different regulatory sign messages, and were

afforded the opportunity to suggest alternative sign messages. This evaluation was undertaken by the following persons:

- Research staff, two persons (Principal Investigator and Graduate Research Assistant).
- Other Transportation Engineering Faculty at Iowa State University, four persons.
- Advisory Panel, five County Engineers.
- Iowa Department of Transportation personnel, two persons (Traffic Engineer and Secondary Road Research Coordinator).

The survey instrument used in this evaluation phase is included in Appendix B to this report.

Results of First Phase Evaluation

The first phase evaluation established a clear preference for a signing system utilizing two or more warning signs with a regulatory sign. The order of preference expressed for the five alternative systems was as follows:

1. Two or more warning signs with a regulatory sign.
2. One warning sign with a regulatory sign.
3. Two or more warning signs, no regulatory sign.
4. One warning sign only.
5. Something resembling the five-sign sequence described.

The research staff concluded from this evaluation that further testing would involve systems including two warning signs and a regulatory sign.

Among the warning sign messages that were evaluated, preference was expressed for the following signs in the order listed:

1. IMPASSABLE DURING HIGH WATER
2. CAUTION FLOOD AREA AHEAD
3. CAUTION WATER OVER ROAD DURING HEAVY RAINS
4. ROADWAY SUBJECT TO FLOODING
5. LOW WATER CROSSING AHEAD
6. HAZARDOUS DURING HIGH WATER
7. FLASH FLOOD AREA
8. HAZARDOUS WHEN WATER ACROSS ROAD
9. WATCH FOR HIGH WATER

Since the decision had been made from the evaluation of signing systems to use two warning signs, the candidate signs listed above were divided into two groups, those most appropriate for the first of two warning signs and those most appropriate as the second sign. Accordingly, the research staff concluded that signs 2, 4, 5, and 7 above would be evaluated further as the first sign and signs 1, 3, 6, 8, and 9 as the second in a sequence of two warning signs to precede a regulatory sign. One subsequent modification was to delete the word CAUTION from the messages in signs 2 and 3. The design, color and shape of a warning sign are believed sufficient to convey a precautionary message so that the use of the word CAUTION was felt not to be necessary.

Assessment of regulatory sign messages indicated essentially equal preference for the following two signs:

DO NOT ENTER WHEN FLOODED

ROAD CLOSED WHEN FLOODED

It was pointed out by some of those particiapting in this analysis that the words ROAD CLOSED appear on a standard regulatory sign used to mark roads that are closed to all traffic. This sign is normally accompanied by appropriate detour signing. Hence, it was concluded that motorists approaching a sign including this message might expect to find some indication of a marked detour. Since provision of a detour for an LWSC that might be flooded a few times a year would generally not be practical, the sign DO NOT ENTER WHEN FLOODED was selected for the regulatory sign to be recommended for use with LWSCs.

Second Phase Evaluation

A second evaluation phase involved the testing of five signing patterns each consisting of two warning signs and one regulatory sign. In each case, the message on the regulatory sign was DO NOT ENTER WHEN FLOODED. The warning sign sequences were as follows:

1. ROADWAY SUBJECT TO FLOODING - HAZARDOUS WHEN WATER ACROSS ROAD
2. FLOOD AREA AHEAD - IMPASSABLE DURING HIGH WATER
3. LOW WATER CROSSING AHEAD - WATER OVER ROAD DURING HEAVY RAINS
4. FLOOD AREA AHEAD - HAZARDOUS DURING HIGH WATER
5. FLASH FLOOD AREA - WATCH FOR HIGH WATER

A color transparency, as reproduced in Appendix C, was prepared to portray a road on which an LWSC might be used with signs appropriately located. The warning sign messages were presented on separate transparent overlays.

The various sign sequences were presented in a specified order to test groups consisting of six sections of four Civil Engineering courses,

one graduate section and five undergraduate sections. One section included only students who were not engineering students whereas the other five sections consisted almost entirely of civil engineering students. The order of the five alternative signing patterns was varied each time they were shown. A total of 71 usable responses was received from this evaluation.

In each presentation, persons in the test group were shown the transparency projected on a screen for approximately five seconds. They were then asked to complete an evaluation form, which is included in Appendix C. This form was designed to assess the correctness of their interpretation of the messages, the correctness of their response to the signs, and the degree of certainty with which they made their assessment.

Results of Second Phase Evaluation

Two possible methods were considered for evaluating the responses to the tests of alternative signing patterns. The first method was based on a total score that included different weights for the answers to questions 1 and 2. The weighting for each answer was based upon the relative degree of correctness of the answer.

Although all of the answers to question 1 suggested an impression on the part of the viewer that would be expected to lead to an appropriate response on the part of a driver who encountered such a sign, the answer "A place where water may fairly frequently flow across the road" was intended to be most nearly correct. (In fact, the answer

"A road passing through a low area that is occasionally flooded" was selected with equal frequency, each being selected about 33.5 percent of the time.)

The desired answer to question 2 was "Proceed with caution but be prepared to stop if necessary." (This answer was selected by 50.3 percent of the viewers while 36.2 percent answered, "None, unless the ditches are flooded, then proceed with extreme caution.")

In the first method of evaluation, scores in a range from 0 to 8 were assigned to each answer for questions 1 and 2. These were added to a scalar value from 0 to 10 representing the response for the degree of certainty felt by the viewer that his or her answers to questions 1 and 2 were correct. On this basis the total score possible ranged from 2 to 26. The mean score received was 17.38 with a standard deviation of 3.80. None of the average values attained by the five alternative signing patterns varied significantly from the overall mean.

A second method of evaluation was based solely on the scalar value for the degree of certainty associated with the responses. The overall mean scalar value in this case was 5.69 with a standard deviation of 2.06.

Although the order of presentation of the alternative signing patterns was different each time they were shown, the number of responses was not the same for each order of presentation. Differences arose because of variations in the sizes of the groups and other factors that were not controlled. A check of the responses indicated a significant bias in the case of the patterns presented first or fifth. The pattern presented first tended to be rated lower than later presentations

and that presented fifth tended to be rated higher. There were no systematic differences noted for the second, third, or fourth patterns presented. Mean scalar values for each pattern were corrected to account for differences in the order of presentation.

The corrected scalar values for each pattern are displayed in Table 3. Values in the third column relate to the probability that a mean value higher than the corrected mean value would have occurred by chance, when comparison is made with a sample consisting of all other patterns.

As indicated in Table 3, patterns 2 and 5 were selected with a significantly greater degree of certainty than the other patterns. These patterns included the following warning sign messages:

- FLOOD AREA AHEAD - IMPASSABLE DURING HIGH WATER
- FLASH FLOOD AREA - WATCH FOR HIGH WATER

It may be noted that the three top-ranked patterns all included the words FLOOD AREA in the first sign and HIGH WATER in the second sign. It is also apparent that the message on the sign LOW WATER CROSSING AHEAD, a sign reportedly used very commonly in several other states, is not clearly understood.

This analysis suggested four signs that should be tested further. Accordingly, a third phase evaluation was undertaken to assess the four signs used in patterns 2 and 5.

Third Phase Evaluation

The third phase evaluation was carried out during a session on low water stream crossings at the Annual Iowa County Engineers

Table 3. Summary of scalar values for certainty of response.

Pattern Number	Corrected Mean Scalar Value	Probability of Higher Mean Scalar Value
1	5.54	0.74
2	5.93	0.13
3	5.36	0.93
4	5.71	0.45
5	5.86	0.21

Conference in December, 1980. The evaluation was conducted in the same manner as the second phase evaluation. Each person in attendance at the session was requested to view five alternative signing patterns and complete the questionnaire included in Appendix C.

The order of presentation could not be varied for this group. Further, it was considered desirable to limit the total number of alternative signing patterns to five. Therefore, the patterns shown first and fifth were not to be evaluated to avoid the bias resulting from their order of showing. Hence, only three warning sign patterns could be evaluated, as follows:

2. FLASH FLOOD AREA - WATCH FOR HIGH WATER
3. FLOOD AREA AHEAD - WATCH FOR HIGH WATER
4. FLASH FLOOD AREA - IMPASSABLE DURING HIGH WATER

Although the signing patterns displayed represented only three of the four possible combinations of the two warning signs being evaluated, it was concluded that an evaluation of the fourth pattern could be deduced from an analysis of the three patterns to be displayed.

Results of Third Phase Evaluation

One hundred twenty-eight usable responses were received during this evaluation phase. As was the case during the second phase evaluation, there were no significant differences among the alternative patterns that could be attributed to differences in the answers to questions 1 and 2. Mean scalar values used to describe the certainty with which these answers were expressed were as follows:

Pattern	Mean Scalar Value
2	5.20
3	5.63
4	5.78

An analysis of these mean values led to the following conclusions:

- Pattern 3 was favored over pattern 2 with a probability of 0.95 that the difference did not occur by chance.
- Pattern 4 was favored over pattern 2 with a probability of 0.98.

Since the first sign was the same in patterns 2 and 4 and the second sign was the same in patterns 2 and 3, this analysis suggested that neither of the signs used in pattern 2 should be included in the preferred pattern of warning signs.

This evaluation led to the conclusion that the two warning signs to be recommended for use would bear the messages FLOOD AREA AHEAD followed by IMPASSABLE DURING HIGH WATER. It is noteworthy that these were the two warning signs ranked highest during the first phase evaluation and that this combination received the highest rating from the second phase evaluation.

None of the signs recommended for use is covered specifically in the Manual on Uniform Traffic Control Devices for Streets and Highways. However, their use is consistent with Sections 2B-44, Other Regulatory Signs, and 2C-41, Other Warning Signs, of the Manual.

IV. CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Experience reported by persons having responsibility for road systems including LWSCs indicates some concern with liability problems growing out of their use. However, a majority of officials having this experience report that they are satisfied with those installations and that highway users seem to accept them.

This experience suggests that a risk analysis generally will indicate that the potential for accidents and liability will be reduced, rather than increased, when an LWSC is substituted for a bridge that is structurally deficient or functionally obsolete. However, it is incumbent upon the official responsible for an LWSC to provide adequate warning of the presence of the facility if the risk of accidents and liability resulting from its use is to be kept within acceptable limits.

One of the conclusions from this research is that the risk of accidents and liability would be further reduced if motorists were discouraged from crossing an LWSC while it was flooded. The findings from an evaluation of alternative signing patterns support this conclusion by suggesting the use of a regulatory sign with the message DO NOT ENTER WHEN FLOODED. The intent of this sign is to preclude passage across the LWSC if the roadway is covered with water. A resolution by the Board of Supervisors should be enacted to afford the necessary legal authority for use of this sign on a county highway.

Although a depth gage is often used in association with an LWSC, erosion sufficient to cause a hazardous condition could occur with a very shallow flow across the road. Consequently, the use of a stream gage is not recommended. Use of delineators is not recommended for the same reason. Furthermore, delineators or a depth gage would tend to catch floating debris and aggravate the problems that occur when an LWSC is flooded.

There was no consistent or commonly accepted pattern of signing associated with LSWCs, according to questionnaire respondents. Hence, no conclusion could be reached directly from their responses. Instead, various combinations of warning and regulatory signs that reportedly are being used were evaluated for use with LWSCs as part of this research. This evaluation process demonstrated a clear preference for the sequence of two warning signs and one regulatory sign that is being recommended.

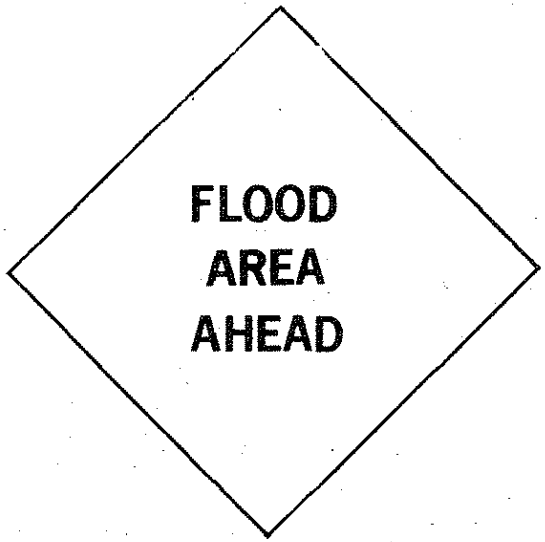
An inevitable result of the use of LWSCs will be an increased need for maintenance of the roadway at locations where they are used. Debris or silt may remain on the roadway after flood waters have receded following inundation of the roadway. Erosion of the road surface may have occurred. Thus, it is essential that road segments including LWSCs be patrolled following heavy rains so that the required maintenance may be performed promptly or that road closure can be effected, if needed.

Recommendations

Use the Signs Indicated in Figure 1

The signs indicated in Figure 1 should be used on each approach to an LWSC. Also indicated in Figure 1 is the recommended placement of each

30" × 30"
BLACK LEGEND
YELLOW BACKGROUND
750 FEET



30" × 30"
BLACK LEGEND
YELLOW BACKGROUND
450 FEET

24" × 30"
BLACK LEGEND
WHITE BACKGROUND
200 FEET

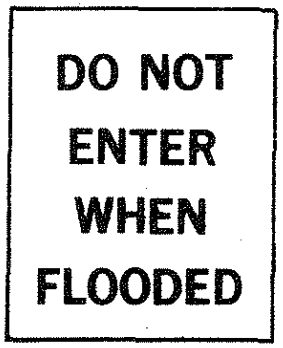


Fig. 1. Signs recommended for installation at low water stream crossing.

sign. Red flags may be used for emphasis during the first year following installation of these signs, if desired. Although these signs are permissible for use according to the Manual on Uniform Traffic Control Devices, it is suggested that the Iowa Department of Transportation request a change in the Manual that would specify the use of these signs in association with LWSCs.

Use a Supplemental Distance Advisory Plate if Needed

A supplemental plate may be used if the location of an LWSC is not apparent from a point approximately 1000 feet in advance of the crossing. This plate would normally display the legend 700 feet and would be used in conjunction with the sign FLOOD AREA AHEAD. The sign would have a black legend on a yellow background and would be 24 in. by 18 in. (similar in size and legend to the supplemental plate used with standard sign W20-8a).

Use an Advisory Speed Plate if Needed

An advisory speed plate (standard sign W13-1) may be used if the maximum recommended speed at an LWSC is less than the speed limit otherwise in effect. If used, the plate should be installed in conjunction with the FLOOD AREA AHEAD sign, unless a supplemental distance advisory plate is used. If a supplemental distance advisory plate is used, the advisory speed plate should be installed in conjunction with the sign IMPASSABLE DURING HIGH WATER. The provisions of Section 2C-35, Manual on Uniform Traffic Control Devices, apply to the design and application of this sign.

Use Low Water Stream Crossings Only on Unpaved Roads

Although the use of LWSCs on paved roads is fairly common in several states, their use on paved roads is not recommended in Iowa. Most paved highways in Iowa have characteristics of geometric design and traffic control that tend to invite travel at high speeds. Experience from other states indicates that the types of problems that may be encountered at LWSCs are inconsistent with driver expectations on high-speed facilities. Since most unpaved roads in Iowa carry very low traffic volumes, the use of LWSCs only on unpaved roads is also consistent with the generally accepted practice of limiting their use to low-volume facilities.

Do Not Use LWSCs on Roads that Provide the Only Access to Dwelling Places Unless Alternative Means of Emergency Access Can Be Provided

The basis for designing an LWSC is to accept that a road will be flooded fairly frequently. If flooding of a road will isolate one or more places of human habitation, an alternative design should be considered unless a suitable means of emergency access can be provided on some other surface route.

APPENDIX A

QUESTIONNAIRE FORM

AND

LETTERS OF TRANSMITTAL

Iowa State University of Science and Technology Ames, Iowa 50010

Engineering Research Institute
College of Engineering
104 Marston Hall
Telephone: 515-294-2336

July 25, 1980

Dear Sir:

In view of the large number of bridges that need to be replaced and the very limited funding available for their replacement, County Engineers in Iowa are anticipating increased use of low water stream crossings in the future. Consequently, the Iowa Department of Transportation is sponsoring research to address problems of liability and traffic control associated with their use. The Engineering Research Institute is carrying out that research.

Although the FHWA is currently conducting research on the design and hydraulic aspects of low water crossings, no previous research is known that has addressed the problems of tort liability or traffic control relating to their use. We anticipate that periodic flooding of the road surface and the resultant possibility of erosion of the roadway will introduce a significant potential to tort liability for highway agencies constructing low water stream crossings.

Your name was given to us as one who has had personal experience with the use of low water stream crossings. We will appreciate your sharing this experience with us by completing the enclosed questionnaire and returning it to us. The questionnaire is very brief, so it will be extremely helpful if you can include additional information such as copies of signing standards, or court documents relating to claimed defects with low water crossings. Additional comments or suggestions will also be welcome. You will also note that in question 2 we have requested the name of any other person of whom you are aware that has had experience with low water stream crossings. We have enclosed a list of the questionnaire recipients in your state to assist you in this respect.

Thank you for your cooperation and assistance in completing and returning the questionnaire.

Sincerely yours,

R. L. Carstens
Professor of Civil Engineering

RLC/dlb
enclosures

QUESTIONNAIRE - LOW WATER STREAM CROSSINGS

Awareness

1. Have you had personal experience with low water stream crossings (LWSC)?

   Yes___ No___

2. Do you know of anyone else in your area who has had personal experience with LWSC?

   Name_____ Title_____

   Address_____

   _____

   If you have no experience with LWSC you may skip the remaining questions and return the survey.

Design and Construction

3. What type(s) of LWSC are used in your jurisdiction? (Indicate the number of each type.)

   (a) Ford (or dip) ____ (d) Other (specify) ____

   (b) Vented ford ____ _____

   (c) Low water bridge ____ _____

4. On what type(s) of highways are LWSC being used? (Indicate the number of each.)

   (a) Paved ____ (b) Unpaved ____

Tort Claims

5. Have you received claims for monetary damages resulting from your use of LWSC?

   Yes____ No____

   If your answer is No, you may skip to question 8.

6. What were the alleged defects leading to the claims? (Indicate the number of each.)

   (a) Vehicle washed away ____ (d) Other (specify) ____

   (b) Roadbed washed out ____ _____

   (c) Road was rough ____ _____

7. What was the approximate dollar amount of the damages claimed in the claims reported in your answer to question 6?

   $_____ (total, all claims)

Traffic Control Devices

8. Do you have a standard method of signing at LWSC?

Yes, state standard ____ No standard ____

Yes, locally developed standard ____

9. Please describe the traffic control devices commonly used.

	Size	Shape	Color	Legend
Warning sign				
Regulatory sign				
Stream gage				
Hazard marker				
Delineator				
Other_____				
_____				
_____				

If possible, please enclose a copy of your signing standards, drawings of any devices, or signing schemes that you feel would be most appropriate.

Additional explanation or information

10.

Questionnaire completed by:

Name and Title_____

Address _____

_____

Return to: R. L. Carstens
Department of Civil Engineering
Iowa State University
Ames, Iowa 50011

Iowa State University of Science and Technology Ames, Iowa 50010

Engineering Research Institute
College of Engineering
104 Marston Hall
Telephone: 515-294-2336

July 30, 1980

Dear Commissioner:

In view of the large number of bridges that need to be replaced and the very limited funding available for their replacement, County Engineers in Iowa are anticipating increased use of low water stream crossings in the future. Consequently, the Iowa Department of Transportation is sponsoring research to address problems of liability and traffic control associated with their use. The Engineering Research Institute is carrying out that research.

Although the FHWA is currently conducting research on the design and hydraulic aspects of low water crossings, no previous research is known that has addressed the problems of tort liability or traffic control relating to their use. We anticipate that periodic flooding of the road surface and the resultant possibility of erosion of the roadway will introduce a significant potential to tort liability for highway agencies constructing low water stream crossings.

Copies of this questionnaire are being sent to all County Commissioners based on a mailing list received from the Association of County Commissioners of Oklahoma. Both Mr. Dwight Kerns, President, and Mr. James M. Winters, Executive Secretary, are interested in the results of this project. We will send a copy of our final report to the Association when the project is completed next May.

The questionnaire is very brief, so it will be extremely helpful if you can include additional information such as copies of signing standards, or court documents relating to claimed defects with low water crossings. Additional comments or suggestions will also be welcome.

Thank you for your cooperation and assistance in completing and returning the questionnaire.

Sincerely yours,

R. L. Carstens
Professor of Civil Engineering

RLC/dlb
enclosure

APPENDIX B

SURVEY INSTRUMENT--
FIRST PHASE EVALUATION
OF SIGNING

Iowa State University of Science and Technology Ames, Iowa 50010

Engineering Research Institute
College of Engineering
104 Marston Hall
Telephone: 515-294-2336

This is written to solicit your assistance in the conduct of Iowa Department of Transportation Research Project HR-218, "Liability and Traffic Control Considerations for Low Level Stream Crossings." We have received over 130 responses from 26 states to a questionnaire sent as part of that research to persons who reportedly have had personal experience with the use of low water stream crossings. Those respondents have reported many different methods of traffic control that varied from no signs to a system using five signs on each approach to the crossing.

You are requested to help us evaluate the systems of traffic control that reportedly are being used in connection with low water stream crossings. We anticipate a two-step evaluation process, this being the first step. A limited number of candidate systems selected during this step, will be evaluated further for effectiveness in the second step. We anticipate use of graphic aids for the second step using groups of students as well as professional engineers. Hopefully, part of that evaluation will be carried out at the County Engineers Conference in December.

Kindly complete each of the three forms enclosed and return them to me at your earliest convenience. Thank you for your assistance.

Sincerely yours,

R. L. Carstens
Professor of Civil Engineering

RLC/dlb
enclosures

FORM OF SIGNING SYSTEM

Please evaluate the general forms of signing systems that are listed below as possible alternatives for use with low water stream crossings. Our objective here is to assess the degree of elaborateness that you feel would be most effective in providing an optimum level of safety in connection with the use of low water stream crossings on rural secondary roads. Subsequent steps in the evaluation process will select the specific signs for use in the system chosen.

Note that a speed advisory plate would also be used if needed in addition to other warning signs in Alternatives B through E. Alternative A, used by a county in Illinois, has five signs in sequence, as follows: CAUTION FLOOD WATER, STOP AHEAD, LOW WATER CROSSING, CAUTION HIGH WATER, STOP.

Please rate one of these alternatives 1, your selection as the best. Rate each of the others either 2, 3, 4, or 5 in accordance with the scale indicated and your assessment as to its effectiveness.

	1 Best	2 Good	3 Fair	4 Poor	5 Would not use
A. Something resembling the five-sign sequence described	____	____	____	____	____
B. Two or more warning signs with a regulatory sign	____	____	____	____	____
C. One warning sign with a regulatory sign	____	____	____	____	____
D. Two or more warning signs, no regulatory sign	____	____	____	____	____
E. One warning sign only	____	____	____	____	____

Comments _____

_____

_____

_____

_____

_____

_____

WARNING SIGNS

The following warning sign messages reportedly are being used by questionnaire respondents in advance of low water stream crossings. Please evaluate these sign messages and rank them according to your assessment of their probable effectiveness in conveying the appropriate warning message. For perspective, assume a vented ford on an unpaved rural road with an ADT of 50 vpd or less. Assume further that only one warning sign (exclusive of a speed advisory plate, used if needed) is to be used. Provide rankings from 1 (most effective) to 10, leaving the space blank following all of the others.

	Message	Rank
1.	CAUTION FLOOD AREA AHEAD	____
2.	CAUTION FLOOD WATER	____
3.	CAUTION WATER OVER ROAD DURING HEAVY RAINS	____
4.	DANGER FLOOD AREA	____
5.	DANGER LOW WATER CROSSING	____
6.	DIP	____
7.	DIP RIVER CROSSING	____
8.	FLASH FLOOD AREA	____
9.	HAZARDOUS DURING HIGH WATER	____
10.	HAZARDOUS WHEN WATER ACROSS ROAD	____
11.	IMPASSABLE DURING HIGH WATER	____
12.	LOW WATER CROSSING	____
13.	LOW WATER CROSSING AHEAD	____
14.	LOW WATER XING	____
15.	POSSIBLE HIGH WATER	____
16.	ROAD OVERFLOWS	____
17.	ROADWAY SUBJECT TO FLOODING	____
18.	SUBJECT TO FLOODING	____
19.	WATCH FOR HIGH WATER	____
20.	WATER CROSSING	____
21.	OTHER (specify) _____	____

REGULATORY SIGNS

The following regulatory sign messages reportedly are in use in advance of low water stream crossings. Please evaluate these sign messages and rank them according to your assessment of their probable effectiveness in conveying the appropriate regulatory message. For perspective, assume a vented ford on an unpaved rural road with an ADT of 50 vpd or less. Assume further that only one regulatory sign is to be used and that it is to be preceded by one or more warning signs in advance of a low water stream crossing. Provide rankings from 1 (most effective) to 3, leaving the space blank following all of the others.

1. DO NOT CROSS DIP WHEN UNDER WATER ____

2. DO NOT DRIVE INTO WATER ____

3. DO NOT ENTER WHEN FLOODED ____

4. ROAD CLOSED WHEN FLOODED ____

5. Other (specify)_____ ____

Comments _____

_____

_____

_____

Completed by _____

_____

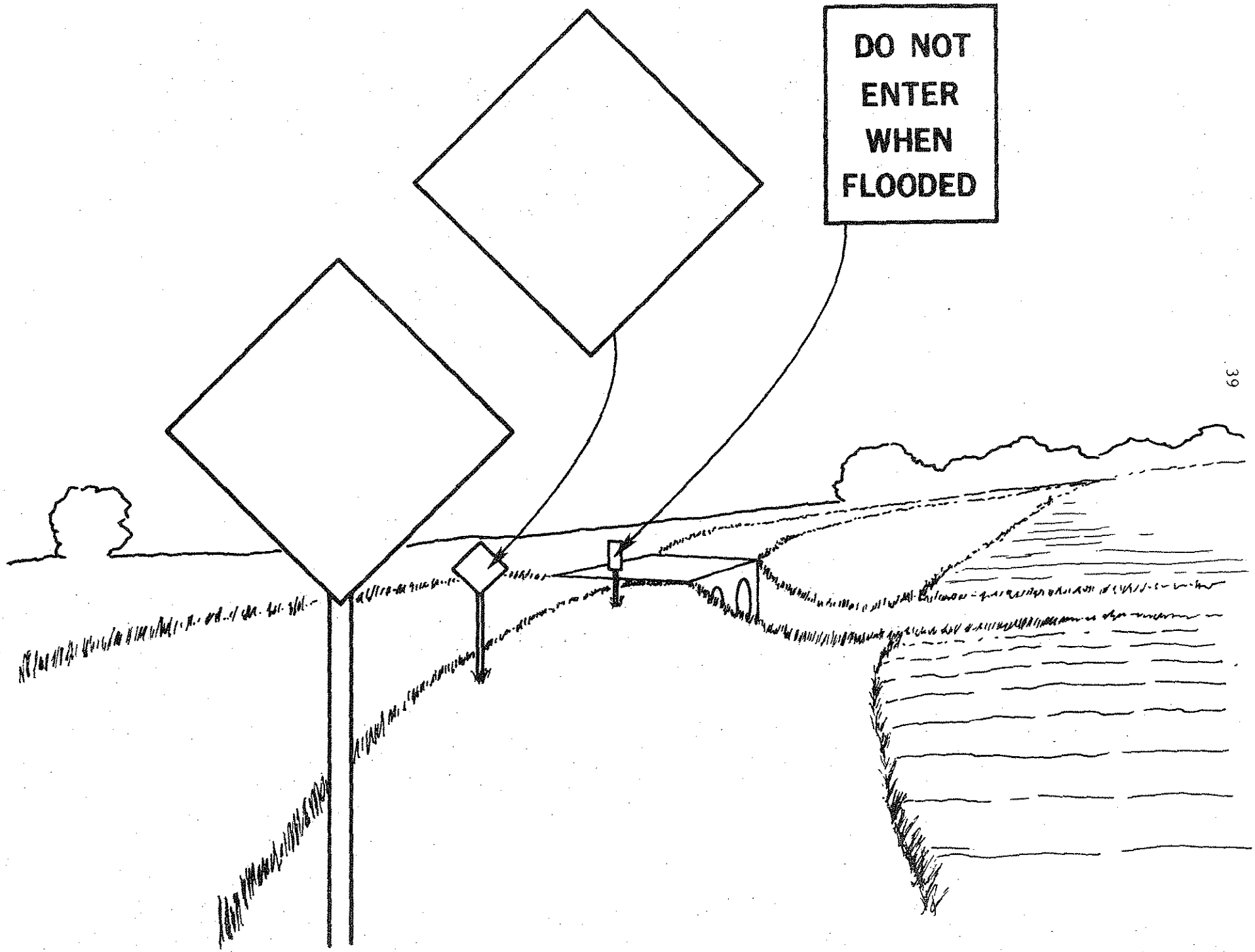
_____

Return completed forms to:

R. L. Carstens
Department of Civil Engineering
Iowa State University
Ames, Iowa 50011

APPENDIX C

SURVEY INSTRUMENT--
SECOND AND THIRD PHASE
EVALUATIONS OF SIGNING


DO NOT
ENTER
WHEN
FLOODED

QUESTIONNAIRE

Research Project HR-218

Circle the letter preceding the one best answer to each of questions 1 and 2.

1. If you, as an automobile driver, were to encounter the signs displayed in the transparency, which of the following would you anticipate?
   a. A bridge where problems have developed following heavy rains.
   b. A road passing through a low area that is occasionally flooded.
   c. A place where water may fairly frequently flow across the road.
   d. A location that is occasionally washed out by runoff from heavy rains.

2. What response does the series of signs displayed in the transparency indicate would be most appropriate?
   a. None, unless the ditches are flooded; then proceed with extreme caution.
   b. Proceed with caution but be prepared to stop if necessary.
   c. Stop, cautiously turn around, and avoid the area.
   d. Probably none, except in the case of a flood that might occur every 25 years or so.

Based upon the information provided by the signs, how certain are you that your answers to questions 1 and 2 are correct? (Indicate by drawing a downward pointing arrow anywhere along the scale below.)

Message from signs is too vague

Message from signs is clear and unambiguous

Do not mark below the line. For office use only.

D _____ N _____

G _____ O _____