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A STATISTICAL SUMMARY OF THE CAUSE AND COST OF BRIDGE FAILURES

F. F. M. Chang

September 1973
Final Report

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16. Abstract

This report presents a statistical summary of the cause and cost of bridge failures based only on a review of damage reports in the FHWA Emergency Relief files for major floods that have occurred during the last few years. As was anticipated, these reports yielded very limited reliable data; so the dollar projections must be viewed accordingly. The general trends, however, should serve as guidelines for future research in related areas.

Of 383 cases, 14.9 percent reported damages to the superstructure, 24.5 percent to the pier, and 71.8 percent to the abutment; in 43.2 percent of the cases, the damage extended to the approach roads. In 341 cases where the causes of failure were either stated in the original files or theorized by the reporter, only 6.9 percent of the failures were attributed to riverbed changes (aggradation and degradation), 29.6 percent were attributed to vigorous change in flow, 38.8 percent to flowpath deficiency, 20 percent to floating debris, and only 4.7 percent to structural deficiency.

The federal government will be spending about $20 million per average year for bridge failure caused by floods in the next few years. This amount does not include the costs that will be incurred by state and local governments.

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A STATISTICAL SUMMARY OF
THE CAUSE AND COST OF BRIDGE FAILURES

Fred F. M. Chang

SEPTEMBER 1973

FINAL REPORT

Prepared for

DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
Office of Research
Washington, D.C. 20590

A STATISTICAL SUMMARY OF THE CAUSE AND COST OF BRIDGE FAILURES

Fred F. M. Chang

PREFACE

Several million dollars are spent every year on repairs and/or replacements of bridges. To curtail this cost, sizable funds are appropriated each year to conduct research related to bridge failure.

This report presents a very brief statistical summary of the cost and cause of bridge failures which occurred during floods in the last few years, in the hope that a guideline for future research areas and allocation of funds will be revealed.

The project was initiated by J. Sterling Jones and Roy E. Trent both of the Federal Highway Administration and conducted by Fred F. M. Chang of Federal City College under Contract DOT-FH-11-8093. The data were supplied by the Office of Engineering, Federal Aid Branch.

The cooperation and assistance received from Fred Verity and Harold Bennett both of the Office of Engineering are deeply appreciated; without their help, this project would not have been completed. Special acknowledgments are due to Murry Corry and Chuck O'Donnel both of the Federal Highway Administration for their valuable comments.

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INTRODUCTION

Bridge failures cost millions of dollars each year in the United States in the repair and restoration of the highway system. In an effort to curtail this cost, government agencies have been conducting various research projects related to scouring around bridge piers and abutments. However, the scour problem is so complicated that their findings are often fragmented and unevaluated, and much more work has yet to be pursued. With limited funds available for hundreds of research proposals, it is important that a priority and emphasis be assigned to each subject.

This paper reports a statistical summary of the causes of bridge failures that occurred during floods in the last few years, with the objective that a guideline for the direction of future research may be recognized from the results.

The following floods were chosen for the study, with the assumption that these floods (comprised of the East and West Coasts and the Midwest) will adequately represent a cross-section of the United States:

1969	California Floods
1969	Midwest Floods
1969	Virginia Floods
1970	Midwest Floods
1972	Agnes Floods along the East Coast

All the data were extracted from the Emergency Relief files at the Office of Engineering, Federal Aid Branch. A large number of files were scanned, and 409 cases of bridge failures each costing more than $ 1000 were studied to identify (or in some cases to "speculate on") the cause of the bridge failures. Only in about 38 percent of the cases was the cause of the failure clearly stated by field engineers who investigated the failure; the remaining data contained only vague descriptions of the damage and made no mention of the possible causes of the failure. In these cases, the causes of the failure were conjectured using the best judgment of the writer. In some cases, however, the writer failed to reach any pertinent conclusion, and the cause of the failure was not determined.

BRIDGE FAILURE

A bridge crossing is composed of three parts: 1. superstructure, 2. substructure consisting of piers and abutments, and 3. approach road. The term "bridge failure" in this report implies that a portion or complete component of the bridge is damaged or dislocated to the extent that it fails to perform its intended functions. The bridge failures treated in this study were only those caused by floods; bridge failures due to tidal wave or earthquake were excluded.

Types of Failure

(a) Superstructure -- Damages to the superstructure may occur when a flood overtops the superstructure. Traffic signs on the superstructure, guard rails, and even members of the truss will be torn and bent. The damage will be more severe if the flow carries large debris. In one case in the study, a 30-ft piece of timber was caught between the truss and severely bent the frame of the truss. Debris and silt are also deposited on the bridge and traffic is disrupted until they are removed.

Another type of failure of the superstructure is induced by the failure of the substructure. A fall of supporting piers or abutments often leads to a total collapse of the superstructure. Even a small displacement of the substructure may cause a deformation in the superstructure which reduces the loading capacity tremendously.

(b) Substructure -- A failure of the substructure generally results from severe scouring of the foundation. As scour around a pier or abutment increases, a loss in bearing capacity may occur due to reduced pier-to-soil contact in the case of friction piles, because of weight loss in the soil above spread footings, or because the uneven removal of foundation soil, causing the pier to slip. Any increase in the L/r ratio of a pier increases the likelihood of structural failure.

For economic reasons, some abutments have been built with timber planks and backfilled with layered gravel and sand. Seemingly, they function satisfactorily when the planks are new. But as they deteriorate, the gaps between the planks become wider, and the swift flow around the abutment gradually siphons out the back fills and creates a large cavity. Finally it induces a total collapse of the entire abutment, dragging down the superstructure with it. Many bridge abutments built with timber planks in Minnesota and South Dakota failed for this reason during the 1969 floods.

For the design of the substructure, engineers generally consider only the vertical loads of the superstructure and traffic, but seldom account for the lateral forces from floating debris and the drag force exerted by passing flow. Several cases of pier damage due to floating debris and ice were observed in the 1969 Midwest floods. Timber bents were broken into two pieces and bents made of steel pipes were bent by the impact of large debris.

In Iowa, there was a case of abutment failure which resulted from the instability of foundation soils. The foundation soils were composed of clay which were submerged in the water during the flood. The entire mass of soils slipped with the abutment when the flood subsided rapidly. With the high water saturation at high flood stage, shear stress in the soil was reduced; then with the sudden drawdown of the flood stage, the water pressure on the abutment that initially kept the soils in place was removed, causing the soils to slump.

(c) Approach Roads -- As the scour of abutment foundations reaches to the backfill, the flooding water tends to flow around the back of the abutment to carry away more backfill. This process accelerates when the flow finds a bypass behind the abutment. The extent of the erosion increases rapidly; it causes a shift of the main channel to flow behind the abutment and wash away the approach roads. Erosion of this type usually occurs at river bends where the flow is concentrated toward the outer bank of the bend, and thus the scour of the foundation tends to become deeper. This phenomenon may shift toward downstream tangent sections due to the natural progression of meandering patterns.

There is another type of erosion on approach roads that results from overtopping flow. This erosion starts from the road surface and proceeds downward. The extent of the erosion is generally wider and shallower. Overtopping may cause two types of failure: 1. the shoulder and downstream embankment may wash out and 2. the paved surface may float and wash out completely.

For visual understanding, a sketch of a typical bridge failure is given in Figure 1.

Causes of Failure

Bridges fail when 1. the flow overtops the superstructure and lateral forces (either from debris or drag) exceed the design capacity, 2. scour around the foundation of the substructure becomes critical, and 3. the capacity of the bridge becomes deficient. The following paragraphs discuss the causes of these phenomena in more detail.

(a) Overtopping Flow -- It is rather obvious that an inadequate flow path forces the flood to overtop the bridge. Bridge clearance is determined from the hydrological study of a design flood of certain magnitude. Therefore, a flood of magnitude larger than the design flood will most probably overtop the bridge.

Most natural rivers undergo constant change; in the riverbed, aggradation and degradation take place continuously. Aggradation occurs where backwater forces sediment in the flow to settle. If a bridge is located in a reach where backwater exists, the clearance of the bridge seemingly sufficient at construction will become inadequate in later years.

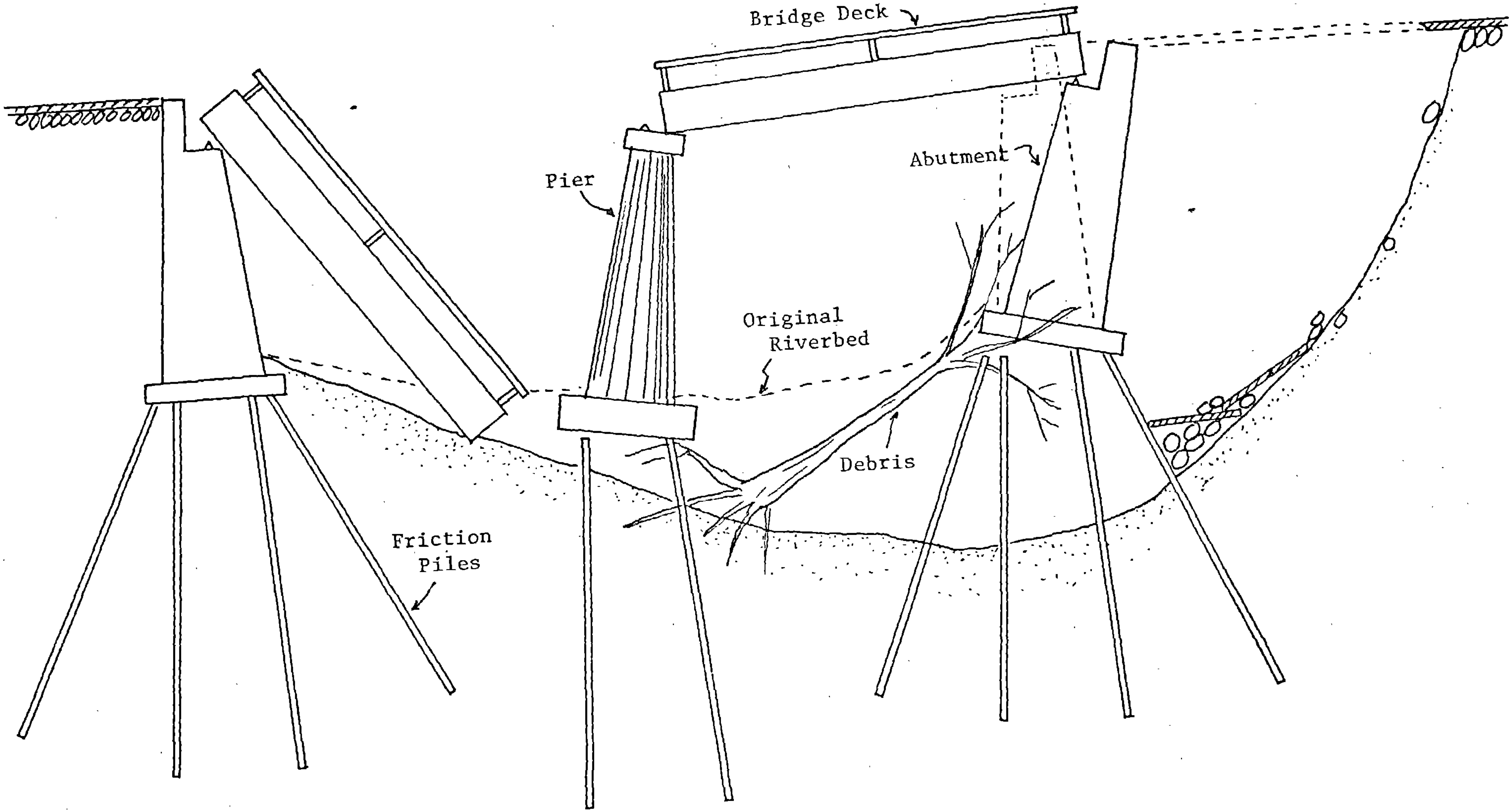

FIGURE 1 TYPICAL MODES OF BRIDGE FAILURE

Floating debris carried by the flood often accumulates around the substructure and obstructs the flow path, causing the flow to overtop the bridge. In quite a few cases in the study, the floating debris plugged the flow path completely, so that the flow was forced to overtop the bridge, finally washing out the bridge entirely.

(b) Scour Around Foundations -- Scour around piers and foundations consists of local scour and general scour. Local scour is the work of the intensive diving flow at the leading edge of the structure. Skewed piers (whose axes are not parallel to oncoming flow) are especially susceptible to local scour because of increased diving flow. The scour hole is ordinarily deep and extends in a rather small area in the immediate vicinity of the structural foundation. General scour normally implies

1. degradation of the streambed due to increased sediment-carrying capacity,
2. erosion of the streambed due to contracted and thus accelerated flow,
3. erosion of the concave bank of a meandering river, as well as
4. the progressive tendency toward equilibrium of an unstable river.

However, two and three could at times be classified as local scour, especially when the erosion is not extensive.

Floating debris not only causes flow to overtop bridges as discussed previously, it also plays a major role in intensifying the erosive action of the flow. A partial blockage of the upper flow path by floating debris brings forth an increase in flow velocity and thus more violent erosive action. The flow is often concentrated downward and impinges on the foundation soils around piers and abutments; if its progress is not checked, it will induce a total collapse of the bridge.

(c) Structural Deficiency -- As the bridge gets older, the materials deteriorate and become more vulnerable to the excessive forces and erosive action of the flow, especially for timber abutments. Many such failures were observed in this study, where timber bents were broken by the impact force of large floating debris, and where the backfill and abutments made of timber were washed away by swift flow. Had these bridges been newly constructed, the failures may not have occurred.

Bridges also fail due to the deficiency in internal strength of foundation soils. Two such cases were found in the study. The entire foundation settled in one case; in the other, the foundation soils slumped down in one lump, bringing the bridge down with them.

The causes of bridge failure can be summarized as follows:

- Overtopping Flow
  1. Under-design of bridge clearance
  2. Extremely large flood
  3. Floating debris
  4. Aggradation of riverbed
- Critical Scour
  5. Degradation of riverbed
  6. River constriction
  7. River bend
  8. Piers and abutments
  9. Floating debris
- Structural Deficiency
  10. Deterioration of materials
  11. Under-design of structural components
  12. Soil failure

Classification of Causes of Failure for Analysis

For analysis, the causes of bridge damage or failure are briefly divided into five categories: 1. Riverbed change, 2. Flow change, 3. Flow path deficiency, 4. Floating debris, and 5. Structural deficiency.

Since no details were given in the original data, aggradation and degradation of the riverbed, and river constriction are combined together as riverbed change. The effects of river bends, skew piers and abutments can be discussed under the category of flow change because the flow characteristics change vigorously with flood stage at river bends and with skewed approaching flow near piers and abutments, causing deep scour that leads to a collapse of the bridge. Whether overtopping flow is caused by under-design of the bridge clearance or an extreme flood is often not too clear, even where detailed data are available; therefore, they are combined as flow path deficiency. However, flow path deficiency caused by floating debris has been combined with the damages of bridge structures due to direct impact of debris in a separate category, floating debris. A broken timber pier or a bent guard rail represent a clear result of this cause. The following cases are included in structural deficiency: failures of older bridges unless the condition of the bridge before the flood was stated as fair, under-design of structural components, and soil failure due to insufficient foundation investigations. It is often difficult to categorize a given failure, especially in light of the limited data that was available for this study.

ANALYSIS OF DATA

For all data, the following items are tabulated in Appendix A: description of bridge, year of construction, location of damage, collapse of bridge, cause of damage, overflow, and total cost of damage.

The files in the Office of Engineering were not particularly designed for the purpose of this study and thus do not contain all the information needed for the analysis. In addition, no unique format was used for reporting the flood damages; therefore, the writer felt that to compile the data in more detail than that appearing in Appendix A would not only be very difficult but quite meaningless. For example, some states reported in much detail while others described bridge damage just as "Bridge damaged beyond repair." In the cases where there was no way to speculate where the damage was located and how it happened, the corresponding items were kept blank.

Ordinarily, bridge failure, like other hydraulic structure failure, is attributed to multiple causes. For example, a flood stage was so high that water overflowed an old bridge at a river bend, and the bridge failed. Much debris remained at the bridge site after the flood. Was this failure attributable to flowpath deficiency, floating debris, concentrated flow at the river bend, or structural deficiency? Would this bridge stand if it were not built at a river bend, if it were new, or if there had been no debris? All these questions are difficult, if not impossible, to answer even where very detailed data were supplied. Therefore, the writer in searching and identifying considered all prevailing causes based on the statements in the files and the attached pictures, and equal weight was given to each of the various causes.

RESULTS AND DISCUSSION

The results of the analysis are tabulated in Table 1. Of 383 cases for which the description of damages was presented, 14.9 percent of the damages occurred at the superstructure, 24.5 percent at the pier, 71.8 percent at the abutment, and in 43.2 percent the damage extended to the approach road. It is also shown that in 25.6 percent of the 383 cases the bridge collapsed entirely; of these about two-thirds were less than 100 feet long.

Among the 341 cases for which the cause of the failure was either stated in the files or theorized by the writer, only 6.9 percent of the failures are attributed to <u>riverbed changes</u> as defined previously. This figure is smaller than the writer, as well as many bridge engineers, expected. Probably, it is due partly to the fact that the field engineers who inspected the sites of the damaged bridges were not aware of slow riverbed changes and therefore did not report them.

The bridge failures attributed to vigorous <u>flow change</u> were 29.6 percent, and those attributed to <u>flowpath deficiency</u> were 38.8 percent. A figure of 38.8 percent for flowpath deficiency is, in the writer's opinion, a little high. This high figure resulted in part from the writer's judgment on the cause of bridge failure and partly from the type of data used in this study, since the Emergency Relief files are restricted to catastrophic floods. In all the cases where overflow was

TABLE 1 SUMMARY OF ANALYSIS

(a)

		Number	Percent, % *
Damage at	Superstructure	57	14.9
	Pier	94	24.5
	Abutment	275	71.8
	Approach Road	165	43.2
Collapse of Bridge		98	25.6

* Percentage of the total number(383) of the cases in which the damage of bridge was described. In some cases, there was overlap in damage categories(For example, both superstructure and pier were destroyed in some cases).

(b)

Cause of Damage	Percent, % **
Riverbed Change	6.9
Flow Change	29.6
Flowpath Deficiency	38.8
Floating Debris	20.0
Structural Deficiency	4.7

** Percentage based on writer's judgement in most cases as it was seldom precisely clear as to which cause of damage was predominate.

indicated, flowpath deficiency was assumed, at least as one of multiple causes. But in reality overflow is not necessarily an indication of flowpath deficiency in all cases, since it can result also from unusual floating debris blocking the waterway and thus creating an insufficient flow path.

Only 4.7 percent of the bridge failures were attributed to structural deficiency.

All these figures are subject to change because (a) in judging the cause of damage, a certain amount of speculation was involved, and (b) this speculation was based on rather scattered data. More detailed and consistent data will surely improve the results; the findings would then be more conclusive. In order to secure better data for this type of analysis in the future, a suggested format for making damage surveys and reports is provided in Appendix B for use by state highway departments.

The cost of highway damage due to floods from 1951 to 1972 is tabulated in Table 2 and graphically represented in Figure 2. An average line is drawn through the data to determine the expected average cost of highway damage in 1974. The extension of the line indicates an amount of about $ 65 million. In Table 3, the total cost of the highway damage for the floods studied in this analysis is shown. A total of $ 162,229,838 was used to restore the highway system; of this, an amount of $ 50,602,301 was spent on the restoration of damaged bridges, that is approximately 31.2 percent. If this same ratio were assumed to hold for the near future, the federal government will be spending about $ 20 million per average year for bridge failures caused by floods in the next few years.

TABLE 2 COSTS OF HIGHWAY DAMAGES DUE TO FLOODS IN THE UNITED STATES

YEAR	COST in $1,000
1951	315
1952	3,347
1953	4,126
1954	2,694
1955	31,198
1956	17,451
1957	12,345
1958	11,494
1959	8,782
1960	1,311
1961	4,748
1962	4,654
1963	4,837
1964	160,317
1965	69,744
1966	7,955
1967	21,491
1968	3,511
1969	86,040
1970	14,317
1971	71,734
1972	115,340

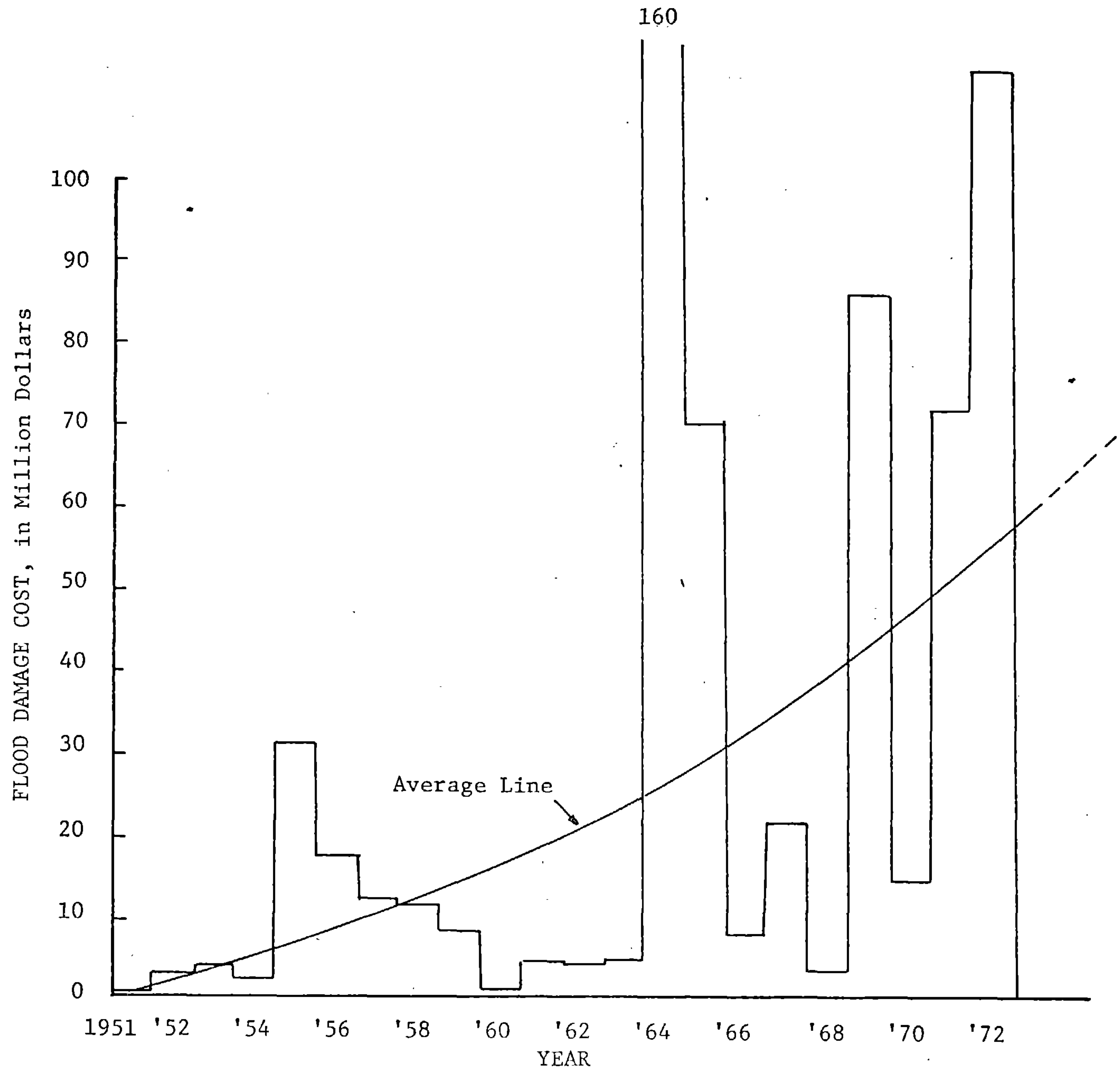

FIGURE 2 COSTS OF FLOOD DAMAGES ON HIGHWAYS IN THE UNITED STATES

Table 3

TOTAL COSTS OF HIGHWAY DAMAGES DUE TO FLOODS

YEAR	STATE	TOTAL COST, in US$ *
1969	California	46,732,239
	Iowa	1,178,757
	Minnesota	5,319,111
	North Dakota	1,516,468
	South Dakota	1,223,226
	Virginia	13,255,796
	Wisconsin	400,617
1970	Minnesota	763,412
	North Dakota	270,938
1972	Maryland	10,441,845
	New York	32,421,100
	Pennsylvania	35,536,188
	Virginia	13,170,141
Total		162,229,838

Note: Data were taken from the files (Emergency Relief) at Federal Aid Branch , FHWA.

* This figure has not been adjusted for construction cost differentials for various states.

This amount does not include the costs that will be incurred by state and local governments.

As to the projection of the total losses per year (in dollars) attributable to various types of scour and erosion, the writer was confronted with a certain difficulty in producing precise and confident results. The figures in Table 1a are based on the counting of the occurrence of the events: the damage at the pier, for instance, occurred 94 times in 383 cases of bridge failures, or 24.5 percent of the time. Since the total cost of the flood damages that were studied was \$ 162 million, can one then conclude that \$ 39.6 million (24.5 % of \$ 162 million) was spent on the repair and restoration of the scoured piers? The answer is no, because (a) in a bridge failure, the damages occur often on more than one component of the bridge, and (b) the cost of repairing each component varies. When a bridge is damaged, both the superstructure and the pier usually need to be repaired. In general, the repair of the superstructure costs more than the repair of a scour hole around the pier. The repair of the superstructure occasionally involves a complete replacement of the entire structure while the repair of the scour hole around the pier foundation needs only a fill of the hole with gravel ripraps. In such a case, a division of the cost evenly between the two parts would be inadequate and misleading. At any rate, more detailed data, such as breakdown figures for the costs of repair, are needed.

With regard to methods of alleviating losses, some corrective measures currently used are described in NCHRP Report No. 5, p. 11. Those measures deal with the direct protection of foundation soils against scouring. Other measures that protect foundation soils indirectly by reducing the intensity of the diving flow are deflection plates around the pier, protective piles installed upstream of the pier, and the controlled approach of the flow to avoid concentration and meandering. In natural rivers, especially wide rivers, variations in flow are vigorous; the direction as well as the intensity of the flow changes rapidly during floods. When the flow concentrates at the pier with a comparatively large angle of attack, scour can easily exceed the anticipated depth and result in the collapse of the bridge.

The corrective measures mentioned here are concerned only with local phenomena, and the most important problem - river regime - has not been considered. A stabilization of the entire river system by river training certainly could alleviate the loss of bridges.

SUGGESTED FURTHER STUDIES

The following studies are suggested for further investigation:

(1) As mentioned previously, the present study should be revised by using more accurate, consistent, and detailed data. In order to collect such data, the appropriate state agencies need to be contacted and requested to complete the questionnaire given in Appendix B. Also, it may be necessary for the investigator to visit the field engineers in order to discuss more extensively the bridge failures which occur during floods. Most importantly, all available photographs taken during and after floods

should be examined thoroughly in order to correctly determine the causes of the failure.

(2) The effectiveness and feasibility of the following corrective measures should be evaluated:

a. A roughened approaching section of the channel to avoid flow concentration,

b. An emergency relief system to mitigate flow in the main channel when the flood exceeds a certain critical high stage.

(3) The on-going effort to evaluate the applicability of existing empirical formulas for scour depth by using field data should be continued.

(4) A warning system should be developed to determine when corrective action must be taken to counteract scour damage before the superstructure becomes endangered.

(5) A study should be conducted to establish criteria for site selection which will include the geologic and geomorphologic characteristics of channel networks and drainage basins in relation to floods of various magnitudes.

Line Number	ER Number	Bridge: Length(ft)	Bridge: Width (ft)	Bridge: Material	Bridge: Year Built	Damage at: Super Structure	Damage at: Pier	Damage at: Abutment	Damage at: Approach Road	Collapse of Bridge	Cause of Damage in %: Riverbed Change	Cause of Damage in %: Flow Change	Cause of Damage in %: Flow Path	Cause of Damage in %: Floating Debris	Cause of Damage in %: Struc. Deficiency	Overflow	Cost in US $
1*	434-1	279	36	conc.			x					50		50			210,000
2	435-5	430	24				x	x	x			50		50			8,000
3	"	40	24				x	x				50		50			7,000
4	"	40	24							x				100			55,000
5*	435-6								x				50	50		x	5,000
6	436-1	40	24	timber			x	x		x							67,000
7	437-1	960	26	girder			x	x		x							360,000
8*	437-4	100	50				x	x			34	33	33				53,000
9*	439-6	1080	17	conc steel	1921		x	x	x				50	50		x	1,028,000
10*	439-10	700	27		1957		x	x				50		50			18,433
11*	439-11	180	17					x	x				50		50	x	98,700
12*	459-9	642	52	RC	1962			x	x	x			100				83,400
13	459-16	390	26	RC						x							127,300
14*	459-31	40	18	timber					x	x		50	50				23,727
15*	460-16	100					x				50			50			29,500
16*	460-18	110	27		1932			x		x		50	50				624,000
17	460-20								x				100			x	5,100
18*	460-22								x				50	50		x	8,300
19*	460-25					x							50	50		x	283,000
20*	463-9					x	x	x	x		50				50		238,000

* Better Data

Line Number	ER Number	Bridge				Damage at				Collapse of Bridge	Cause of Damage in %					Overflow	Cost in US $
		Length(ft)	Width (ft)	Material	Year Built	Super Structure	Pier	Abutment	Approach Road		Riverbed Change	Flow Change	Flow Path	Floating Debris	Struc. Deficiency		
*21	469-1	550					x			x	50			50			401,000
22	471-1	57	44	conc			x			x							76,000
23	471-2	50		timber conc			x	x	x				100				50,000
24	471-16	44	24	PCC				x				100					3,000
25	476-1							x				100					
26	"			timber PCC	1937		x	x				100					58,750
*27	478-1							x	x	x			50	50		x	112,800
*28	479-1							x				50		50			10,300
29	481-1						x	x				100					88,000
*30	"					x							100			x	3,500
31	"							x									9,000
*32	"							x					100			x	11,000
33	"						x							100			6,300
*34	481-2					x							50	50		x	3,850
35	482-1						x			x				100			
36	"						x							100			
37	"						x	x	x				50	50			28,500
38	485-1	50	32	timber	old					x							107,500
*39	486-1	96	24	timber	1936		x		x				100				85,500
40	487-6	135	24	timber conc			x	x				50	50				174,500

Line Number	ER Number	Bridge				Damage at				Collapse of Bridge	Cause of Damage in %					Overflow	Cost in US $
		Length(ft)	Width (ft)	Material	Year Built	Super Structure	Pier	Abutment	Approach Road		Riverbed Change	Flow Change	Flow Path	Floating Debris	Struc. Deficiency		
41	488-2							x	x			50	50			x	16,500
*42	490-1							x				100					10,500
43	"							x					100			x	13,500
*44	"					x	x	x			34		33	33			60,000
*45	"	196	66	CGC			x							100			5,000
*46	493-3	950	59	SGA		x							50	50			605,000
*47	503-1	33	29	FCC				x			34		33	33		x	22,000
*48	"					x		x					50	50		x	35,500
*49	"							x	x				50	50		x	4,000
*50	"								x				50	50		x	11,800
*51	510-1	100	40	PCC				x					100			x	83,100
*52	511-2	165	37				x							100			21,400
*53	511-4	721	28					x	x					100			12,700
*54	511-7							x					100				46,160
*55	513-1					x		x			50			50			390,000
56	"	93	58	CSC				x	x			100					11,000
*57	"	65	69					x			50	50					15,000
*58	515-1							x	x	x	50		50				85,000
*59	523-1	40	61						x				50	50		x	16,000
*60	541-2	121	28	Steel	1968			x				34	33	33			17,500

Line Number	ER Number	Bridge: Length(ft)	Bridge: Width (ft)	Bridge: Material	Bridge: Year Built	Damage at: Super Structure	Damage at: Pier	Damage at: Abutment	Damage at: Approach Road	Collapse of Bridge	Cause of Damage in %: Riverbed Change	Cause of Damage in %: Flow Change	Cause of Damage in %: Flow Path	Cause of Damage in %: Floating Debris	Cause of Damage in %: Struc. Deficiency	Overflow	Cost in US $
* 61	541-8	42	29	timber		x	x	x			25	25	25	25		x	50,000
* 62	542-6	100	21				x		x	x	34	33	33				
* 63	"	90	21				x		x	x	34	33	33				
* 64	"	129	21				x		x	x	34	33	33				911,400
* 65	543-2	50	64					x			50	50					13,300
66	"	36	28					x				100					16,000
67	548-2			RC			x	x			100						3,950
* 68	550-2	102	42	CGC				x			100						12,000
* 69	551-1								x		50		50			x	1,500
* 70	552-1							x				100					4,500
* 71	553-2				1968							50	50				91,500
* 72	561-2	87	28					x				50		50			162,600
73	561-3	50					x	x					100				6,000
* 74	564-1	408	26	CSE	1938		x	x		x		100					575,000
* 75	584-1								x				50	50		x	36,600
* 76	586-2	15	20					x				50		50			4,450
* 77	"	59	20					x	x			34	33	33		x	58,360
* 78	"	70	20				x	x				100					14,800
* 79	"	100	20					x					50	50		x	11,500
* 80	"						x	x			50	50					4,000

		Bridge				Damage at					Cause of Damage in %						
Line Number	ER Number	Length (ft)	Width (ft)	Material	Year Built	Super Structure	Pier	Abutment	Approach Road	Collapse of Bridge	Riverbed Change	Flow Change	Flow Path	Floating Debris	Struc. Deficiency	Overflow	Cost in US $
*81	586-2	80	20					x		x		50		50			43,800
*82	587-1	95	34	conc			x	x				100					8,800
*83	617-1	100	36					x			50			50			80,000
84	617-3	47	27	timber			x						100				2,000
*85	637-1	132	23	conc	1921		x					34	33	33			116,350
*86	78-2	105	30	CDG	1953			x	x				100			x	45,000
*87	78-12	109	30	BS	1967			x	x				100				5,000
*88	78-15	106	30				x	x	x			50	50				8,000
*89	78-16	48	17		1920			x	x			50	50				2,500
*90	78-17	36	24	timber	'60		x	x	x				50	50			95,740
*91	78-19	62	24		1960			x	x	x			50	50			100,700
*92	78-20	143	20		1937	x	x	x		x		50	50				324,000
*93	78-21	110	34	steel				x				100					5,000
94	78-23	62	24		1957			x	x				50	50		x	90,000
*95	78-24	96	26		1959		x					50		50			20,000
*96	78-25	67	15		1908			x	x			50	50				6,000
*97	78-22	60	24		1950		x	x	x	x			34	33	33		117,000
98	113-2	100	18	timber	'50			x				50			50		16,000
99	113-3	34	18	"				x				50			50		7,022
*100	129-2	102	19	"	1924			x		x		34	33		33	x	134,610

Line Number	ER Number	Bridge				Damage at				Collapse of Bridge	Cause of Damage in %					Overflow	Cost in US $
		Length(ft)	Width (ft)	Material	Year Built	Super Structure	Pier	Abutment	Approach Road		Riverbed Change	Flow Change	Flow Path	Floating Debris	Struc. Deficiency		
*101	130-3	51	18					x			34	33			33		2,700
*102	145-2	30	20	steel	1958			x		x			100			x	48,370
*103	145-3	41	29		1964			x				50			50		14,740
*104	145-4	31	28					x		x			50		50	x	58,360
*105	145-5	51	18		1912			x				34	33	33		x	8,600
*106	145-7	100	22		1967			x				50			50		1,800
*107	69-11	386	15	steel	1896		x	x	x	x	50	50					1,605,070
108	69-31	23	16		1900			x		x		100					60,700
*109	70-13	104	28	timber	1962		x	x	x	x			100			x	144,440
110	71-3	113	19	timber	1930					x			100				245,000
*111	71-39	83	28		1951			x			50				50		6,008
*112	71-41	93	28		1940		x	x			34			33	33		8,680
*113	72-13	219	24		1956		x	x		x					100		638,000
114	72-49	410	23				x					50	50				15,865
*115	72-50	160	28	steel				x			50	50					8,455
116	72-52	150	30		1949		x	x									1,985
117	72-55	100	19	steel	1924			x	x			100					8,432
*118	72-56	162	48		1954		x	x					100			x	2,733
*119	72-63	90	30	conc	1955			x				100					6,008
*120	21-2	27	26	conc	1962			x				50			50		1,751

		Bridge				Damage at					Cause of Damage in %						
Line Number	ER Number	Length(ft)	Width (ft)	Material	Year Built	Super Structure	Pier	Abutment	Approach Road	Collapse of Bridge	Riverbed Change	Flow Change	Flow Path	Floating Debris	Struc. Deficiency	Overflow	Cost in US $
121*	21-3	94	30	conc	1963			x	x		100						5,346
122*	21-4	32	28	conc					x				100			x	4,110
123*	21-6	28	26	steel					x				100			x	1,121
124*	21-7	54	16	steel	old			x	x	x		100					21,800
125*	21-9	32	20				x	x		x			100			x	29,627
126*	21-10	100	24	timber			x	x	x	x		50			50		
127*	"	108	30	conc				x				50	50			x	39,829
128*	21-15	117	28	conc			x	x				100					4,950
129*	21-22	32	30	PCC				x	x	x			100			x	21,800
130*	21-25	50	30	PCC			x	x	x	x		34	33		33	x	33,645
131*	21-36	24	24	timber				x		x			100			x	9,000
132*	21-39	56	30	conc				x	x				100			x	8,955
133*	21-40	250	16	timber					x			34	33	33		x	2,100
134*	21-48	128	30	conc				x			50	50					1,500
135	21-50	118	30	conc				x				100					1,766
136	21-56	36	29	conc				x						50	50		3,400
137*	21-57	52	30	conc			x	x				50		50			4,600
138	21-59	100	30	PCC				x	x			25	25	25	25		16,524
139*	21-60	128	30	PCC	1961		x			x			50	50			89,527
140	21-61	60	28	conc				x	x			50	50				1,744

Line Number	ER Number	Bridge				Damage at				Collapse of Bridge	Cause of Damage in %					Overflow	Cost in US $
		Length(ft)	Width (ft)	Material	Year Built	Super Structure	Pier	Abutment	Approach Road		Riverbed Change	Flow Change	Flow Path	Floating Debris	Struc. Deficiency		
141*	21-62	119	30	conc				x	x		50	50					
*142	"	93	30	"				x	x		50	50					7,850
143	21-63	400	24	conc				x	x			50	50				13,210
144	21-69	86			1967			x									20,900
145	21-68							x	x				100			x	6,100
146	21-69							x					100			x	10,344
147	21-71				1959			x	x			50	50				6,800
148	21-72							x	x			50	50				24,500
149	21-74							x	x			50	50			x	5,657
*150	21-77	25	24					x	x		50		50				10,112
*151	21-81	86	30					x					100				5,600
*152	21-82	24	28					x	x		34	33	33				1,645
153	21-83	360						x	x			50	50			x	1,886
*154	21-84							x	x			100					10,900
*155	"							x				100					7,904
*156	21-85							x				100					3,558
*157	109-2	75	24	conc	1934			x				50	50				4,800
158	114-1	60	18				x	x		x			100			x	50,090
159	118-3	66	24	timber			x	x		x		50	50			x	126,520
*160	128-1	31	22					x		x			100			x	95,000

Line Number	ER Number	Bridge				Damage at				Collapse of Bridge	Cause of Damage in %					Overflow	Cost in US $
		Length (ft)	Width (ft)	Material	Year Built	Super Structure	Pier	Abutment	Approach Road		Riverbed Change	Flow Change	Flow Path	Floating Debris	Struc. Deficiency		
161	140-3	30	20					x				50	50				23,000
162	146-2	28	23					x		x		50	50				61,530
163*	3-1	100	30				x	x				50	50				59,890
164	44-4	128	16				x					100					17,600
165*	44-6	60	16				x	x				50		50			5,599
166*	44-7	28	32					x	x			50	50			x	3,770
167	45-8	320	28			x		x	x			50	50			x	50,240
168*	48-5	119	16	steel		x		x				34	33	33		x	11,820
169	59-2	25	16					x				100					13,728
170*	64-2	216	16					x					34	33	33	x	3,674
171*	66-4	150	16				x	x	x				50	50		x	22,926
172	66-5	50	18					x	x				100			x	
173	"	160	18					x	x				100			x	9,350
174	81-1	200	20					x				100					15,132
175*	15-2	180	28		1923		x	x							100		75,938
176*	18-1	150	24					x				100					
177*	"	458	24					x				100					74,962
178*	26-2						x	x				34	33	33		x	16,730
179	17-5	104	38	steel				x			50		50				11,800
180	18-1	72	15	steel				x	x	x		100					1,092,000

Line Number	ER Number	Bridge				Damage at				Collapse of Bridge	Cause of Damage in %					Overflow	Cost in US $
		Length(ft)	Width (ft)	Material	Year Built	Super Structure	Pier	Abutment	Approach Road		Riverbed Change	Flow Change	Flow Path	Floating Debris	Struc. Deficiency		
181	19-1	768	33					x	x	x							832,000
182	19-3	80	11	steel				x	x	x		100					112,320
183	19-4					x			x				50	50		x	2,000
184	"								x								1,300
185	"								X				100			x	3,500
186	19-48								x								1,500
187	20-1	205	20					x	x				100			x	124,800
188	20-4									x				100			9,900
189	20-2	7 bridges															1,611,080
190	20-6								x								3,350
191	20-8	2 bridges						x	x								3,650
192	20-11							x									2,000
193	21-2							x	x								15,000
194	"							x	x								3,000
195	21-3	215	28	conc		x			x								335,000
196	21-4							x	x	x							38,500
197	22-3	200	18	timber						x							210,080
198	22-4	115	11	steel						x							171,787
199	22-5	3 bridges								x							64,600
200	22-6	99	28							x							107411

Line Number	ER Number	Bridge				Damage at				Collapse of Bridge	Cause of Damage in %					Overflow	Cost in US $
		Length(ft)	Width (ft)	Material	Year Built	Super Structure	Pier	Abutment	Approach Road		Riverbed Change	Flow Change	Flow Path	Floating Debris	Struc. Deficiency		
201	22-7	3 bridges								x							101,840
202	22-8	3 bridges				x				x x x				100		x	512,088
203	22-9	235	24	steel						x							226,971
204	22-11								x			50	50				10,550
205	"								x			50	50				9,600
206	22-13	36	20	steel						x							49,920
207	22-14					x		x	x				50	50		x	22,500
208	22-15	47	11	steel						x							157,618
209	22-16							x									2,300
210	22-7	272	24			x								100			23,300
211	26-1							x				100					1,150
212	"					x								100			5,800
213	"							x					100				3,000
214	28-1	20	18					x							100		4,500
215	28-3							x	x			100					6,000
216	"								x				100			x	5,000
217	"			steel				x									12,000
218	32-1	15	20			x		x	x	x							12,000
219	33-2	98	23	conc					x	x							104,000
220	33-3							x									9,000

Line Number	ER Number	Bridge				Damage at				Collapse of Bridge	Cause of Damage in %					Overflow	Cost in US $
		Length (ft)	Width (ft)	Material	Year Built	Super Structure	Pier	Abutment	Approach Road		Riverbed Change	Flow Change	Flow Path	Floating Debris	Struc. Deficiency		
221	33-3	18	32							x							42,000
222	"								x				50	50		x	2,900
223	"								x					100		x	2,300
224	"							x									1,500
225	"	44	20					x									11,000
226	"								x					100			1,950
227	"								x								12,000
228	"	175	24					x	x								21,000
229						x			x				100			x	39,000
230	33-4								x				50	50		x	7,000
231	"						x		x			100					16,000
232	33-5							x	x				50	50		x	34,600
233	34-2						x										1,700
234	"							x									3,500
235	35-1	40						x	x						100		3,300
236	36-1	22	30	conc					x								50,000
237	1-1	102	30	steel	1956		x										460,702
238*	1-7	42	49	conc			x	x	x	x			50	50			734,634
239*	1-8	46		conc			x	x		x		100					315,361
240*	1-10	30		stone					x	x			100				162,800

		Bridge				Damage at					Cause of Damage in %						
Line Number	ER Number	Length(ft)	Width (ft)	Material	Year Built	Super Structure	Pier	Abutment	Approach Road	Collapse of Bridge	Riverbed Change	Flow Change	Flow Path	Floating Debris	Struc. Deficiency	Overflow	Cost in US $
241*	1-11	57	31		1932		x			x		100					215,657
242	1-12	70	18	RC	1930		x	x					100				316,788
243	1-15	72	40	conc	1929		x	x		x		50	50				1,144,580
244	1-19	80	30	steel	1952			x			50		50				60,500
245	1-21	106	34						x								10,000
246	1-35			steel	1965			x				100					25,000
247	"							x	x				100				38,025
248	1-23							x	x				100			x	2,000
249	"	60	22	conc			x			x							77,000
250	"	120	44		1967	x		x	x				50	50		x	16,500
251	"	45	24	conc		x		x		x			50	50		x	1,000
252	"					x			x				50	50		x	9,500
253	"					x			x				50	50		x	1,600
254	"					x	x	x	x				50	50		x	6,500
255	"					x		x	x				50	50		x	2,000
256	"					x		x	x				50	50		x	1,000
257	"	140	15		old	x				x				50	50		2,000
258	"	180	24			x			x					50	50	x	3,500
259	1-29							x	x				50	50			1,000
260	"							x	x				50	50			6,242

Line Number	ER Number	Bridge				Damage at				Collapse of Bridge	Cause of Damage in %					Overflow	Cost in US $
		Length(ft)	Width (ft)	Material	Year Built	Super Structure	Pier	Abutment	Approach Road		Riverbed Change	Flow Change	Flow Path	Floating Debris	Struc. Deficiency		
261	1-29	25						x				50		50			2,151
262	1-33			timber						x			100				1,000
263	1-36							x	x				100				2,000
264	"							x				50	50				3,100
265	"	39	16	steel				x				100					5,400
266	"	180	26	steel				x					100				2,300
267	1-40	235	18						x				100			x	3,000
268	1-41	50	12	RC				x	x				100				129,320
269	1-42	40	18	steel				x	x				100				211,046
270	1-49		72					x				100					71,486
271	1-50							x			100						78,903
* 272	1-43	200	50	RC		x			x				50	50		x	65,000
* 273	111-1			conc	old		x	x			50		50				25,879
* 274	111-8	30	22	conc		x		x		x		100					93,500
275	112-4							x									29,000
* 276	112-13	196	13	steel	1898			x				100					431,300
* 277	114-7	47	36					x		x		50		50			312,000
* 278	116-100	90	30	conc		x		x			50	50					405,000
* 279	116-108	160	18		1904			x			34	33		33			275,000
280	116-125	40	20	conc						x							495,000

Line Number	ER Number	Bridge				Damage at				Collapse of Bridge	Cause of Damage in %					Overflow	Cost in US $
		Length (ft)	Width (ft)	Material	Year Built	Super Structure	Pier	Abutment	Approach Road		Riverbed Change	Flow Change	Flow Path	Floating Debris	Struc. Deficiency		
281	116-134	70	30			x	x	x		x	50	50					271,800
*282	116-141							x		x	34	33	33			x	243,000
283	116-142	50								x			50	50			76,500
284	116-143	25								x		100					36,500
*285	116-151	100	24	steel				x	x	x		50		50		x	405,000
*286	116-154							x		x	34	33	33			x	2,580,000
287	116-158	400		steel	old		x	x		x			100			x	288,500
288	116-163												100				296,000
*289	118-24			steel	old	x		x		x	50			50		x	285,000
290	118-3							x									58,200
291	118-29			stone	old			x					50		50		4,400
*292	116-103	130	30	steel	1891		x	x	x		50	50					1,454,750
*293	131-19	33	18					x			50		50				122,781
*294	131-25	100	28	steel				x	x	x		34	33	33		x	228,011
*295	131-28	24	16	conc				x		x	50	50					218,808
*296	131-30	80	30	conc				x		x		100					253,006
*297	131-31	15	22					x	x	x			100			x	
298	"	60	24					x	x	x							307,515
*299	131-33	80	20				x	x		x	25		25	25	25		119,349
*300	131-26	50	30					x		x		100					173,459

		Bridge				Damage at					Cause of Damage in %						
Line Number	ER Number	Length(ft)	Width (ft)	Material	Year Built	Super Structure	Pier	Abutment	Approach Road	Collapse of Bridge	Riverbed Change	Flow Change	Flow Path	Floating Debris	Struc. Deficiency	Overflow	Cost in US $
301	131-52	70	24	stone		x			x	x			100			x	129,622
* 302	131-74	119	20	RC			x	x	x	x	50		50			x	799,137
303	131-85	271	15	steel						x							1,140,203
304	131-87	9	18	stone	old					x							50,880
305	131-96	18	32	conc		x		x		x			100				132,135
306	131-99	142	22				x		x					100			573,564
* 307	131-24							x		x			50	50		x	394,574
308	131-49	1390		steel	1906		x			x							4,084,113
309	37-1	181	11	steel	old								50	50			344,640
310	39-1	80						x	x	x		100					178,000
311	39-2	32	38					x				100					36,000
312	"	64	48			x		x	x				50	50		x	3,448
313	39-3	40						x	x	x			50	50		x	587,000
314	39-4	1063	24				x	x		x		100					3,108,000
315	39-5	43	65			x		x	x				100			x	18,000
316	40-1	208	16	steel				x				100					2,130,000
317	40-5	866	41	steel			x										50,000
318	43-2	135															400,204
319	44-3	23	19					x									2,000
320	46-1	30	16					x	x			100					3,200

Line Number	ER Number	Bridge				Damage at				Collapse of Bridge	Cause of Damage in %					Overflow	Cost in US $
		Length (ft)	Width (ft)	Material	Year Built	Super Structure	Pier	Abutment	Approach Road		Riverbed Change	Flow Change	Flow Path	Floating Debris	Struc. Deficiency		
321	46-1	40		steel				x	x				100			x	18,500
322	47-1	40		steel				x	x			50	50			x	1,600
323	47-2								x				100			x	3,000
324	"								x				100			x	6,000
325	"							x	x							x	2,500
326	48-1	51	18	steel				x	x								93,000
327	48-3						x										1,644
328	59-1								x				100			x	1,500
329	1-4					x		x	x				100			x	33,100
330	1-6	48	12	steel				x				100					3,000
331	1-9	296	23			x			x				50	50		x	6,000
332	1-5								x								1,800
333	"	78	23						x				50	50		x	8,000
334	"	78	16					x	x								6,000
335	"					x							100			x	5,000
336	"	13	21					x					100			x	28,000
337	"	21	15			x			x				100			x	7,900
338	"	14	15			x		x	x				100				5,300
339	"					x			x				100			x	6,700
340	"								x								1,500

Line Number	ER Number	Bridge				Damage at				Collapse of Bridge	Cause of Damage in %					Overflow	Cost in US $
		Length(ft)	Width (ft)	Material	Year Built	Super Structure	Pier	Abutment	Approach Road		Riverbed Change	Flow Change	Flow Path	Floating Debris	Struc. Deficiency		
341	1-9	78	23			x			x				50	50		x	8,000
342	"	78	16						x				100			x	6,000
343	"	60	20	conc		x			x				100			x	6,700
344	"	21	15	steel		x			x								5,100
345	8-2	427	38	steel				x									6,800
346	"							x						100			4,650
347	"							x						100			5,200
348	8-4							x						100			5,800
349	"	128	28	steel				x					100				4,000
350	18-2	84	28			x		x	x					100		x	226,020
351	18-3								x								8,455
352	18-4	78	28			x				x							191,445
353	18-5	113	20	conc				x				100					3,000
354	"	25	19					x				100					1,800
355	19-7						x	x					50	50		x	118,557
356	20-14	188	22						x				50	50		x	2,870
357	20-16	52	24	steel				x						100			9,500
358	21-12	126	22	conc								50	50				5,150
359	22-18	73	11	timber				x	x			50		50			305,802
360*	22-20	14	32	conc				x						100			3,060

Line Number	ER Number	Bridge				Damage at				Collapse of Bridge	Cause of Damage in %					Overflow	Cost in US $
		Length(ft)	Width (ft)	Material	Year Built	Super Structure	Pier	Abutment	Approach Road		Riverbed Change	Flow Change	Flow Path	Floating Debris	Struc. Deficiency		
361*	22-20	217	28	conc				x				50		50			16,800
362*	"	145	29					x	x			50		50			29,226
363*	22-21	735		steel		x							50	50		x	5,000
364	"							x					100			x	9,560
365*	"					x							50	50		x	21,000
366*	22-22								x					100			4,625
367	22-23	770					x						50	50			7,710
368	22-25	117	30				x							100			10,500
369	46-2	30	22	steel			x	x							100		40,000
370	25-3	65	23	conc				x				50		50			4,000
371	26-5	80	16				x										10,000
372	27-4	840	34			x	x			x							1,378,000
373	27-6			steel		x			x				50	50		x	125,231
374	28-5	138	11	steel		x							50	50		x	1,500
375	33-6	46	28	steel				x				50	50				151,228
376	53-2	137	38	steel								100					10,000
377*	55-1	129	24				x	x			50	50					9,500
378*	"	129					x				50	50					6,000
379	55-2	80	20	steel				x	x			50	50			x	5,000
380	"	154	20	"				x	x				50		50	x	21,500

Line Number	ER Number	Bridge				Damage at				Collapse of Bridge	Cause of Damage in %					Overflow	Cost in US $
		Length(ft)	Width (ft)	Material	Year Built	Super Structure	Pier	Abutment	Approach Road		Riverbed Change	Flow Change	Flow Path	Floating Debris	Struc. Deficiency		
381	55-2							x	x								2,000
382	"							x	x								1,500
383	"					x		x	x			50	50			x	6,000
384	57-2	100	28	steel				x				100					2,000
385	58-1	172	28	conc				x				50		50			15,000
386	60-1	16	50	conc				x									17,000
*387	61-1	270	24	steel				x			34		33	33			11,500
388	"	350	18				x							100			1,000
389	62-2	35	30	conc				x	x			100					3,250
390	72-2	53	24	conc			x	x	x			34	33	33		x	6,750
391	73-2							x					100				11,640
392	76-1	16	23						x				100			x	2,500
*393	77-2	330	22	steel			x					34	33	33			1,600
394	79-2								x								1,500
395	"								x								2,400
396	80-2	18	21	steel				x									1,200
397	83-1							x					50	50		x	1,000
398	"							x	x				100			x	4,900
399	84-1	20	15	conc				x				100					1,500
400	"	52	16					x				100					1,080

Line Number	ER Number	Bridge				Damage at				Collapse of Bridge	Cause of Damage in %					Overflow	Cost in US $
		Length(ft)	Width (ft)	Material	Year Built	Super Structure	Pier	Abutment	Approach Road		Riverbed Change	Flow Change	Flow Path	Floating Debris	Struc. Deficiency		
401	85-1	18	37	conc				x				100					1,200
402	"	98	20	steel				x					100				11,000
403	"	22	19	steel					x				50		50	x	1,100
404	86-1	34	19	steel		x		x	x	x			100			x	3,000
405	"	100	28	steel				x				100					2,400
406	86-2								x				100			x	4,250
407	"	61	11	steel		x							100			x	1,000
408	"							x	x								1,550
409	"							x	x								2,200

APPENDIX B. PROPOSED BRIDGE FAILURE REPORT

I.D. No. Date :
Location State: Bridge No. :
County: Highway No.:
Town : Over(River):
Time of Failure:

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[1] BRIDGE.

A. Year of Construction:

B. Superstructure:
Type:
Length= ft. Width= ft.
No. of Spans= Max. Span= ft. Min. Span= ft.
Clearance from Design Flood Stage= ft.
Alignment with Center Line of River= °

C. Substructure:
1. Bent:
Type: Pier Pile Other
Material:
Shape:
Length= ft. Width= ft. Height= ft.
No. of Piers(or Piles) at Each Bent=
Type of Web: Beam Frame Wall Other
Alignment with Center Line of Bridge= °
2. Abutment:
Type:
Spur Dike: Yes No
3. Foundation:
Type: Spread Footing Caisson
Friction Piles: Yes No If Yes, answer the Followings
No. of Piles per Footing= Material:
Diameter of Pile= in.
Length of Pile = ft.
4. Foundation Soil:
Classification:
Protective Measure(If Any):

[2] RIVER CHARACTERISTICS.

A. Geometry of Approaching Channel:
Length of Straight Reach= ft.
Slope= Effective Width= ft

B. Stability of Riverbed:
Degradation of Riverbed= ft/yr.
Shifting of Thalweg: No Little Some Frequent
Depth to Bedrock= ft.

C. River Improvement and Construction:

C. River Improvement and Construction:
Dredging Floodway Cutoff Revetment Levee
Dike Lock Dam
Description:

Location from Bridge= mi. Up(Down)stream

[3] FLOW CHARACTERISTICS.

A. Estimated Flood for Design:
Discharge= cfs Recurrence Interval= yr.
Stage from Lower Edge of Superstructure = ft.
Stage from Average Riverbed = ft.

B. Actual Flood:
Discharge= cfs Recurrence Interval= yr.
Stage from Lower Edge of Superstructure = ft.
Floating Debris: Timber Ice Other
-Quantity: None Few Some Many
Transverse Flow from Highway Drainage: No Yes
Relief Flow over Approaching Road : No Yes

[4] POST FLOOD SURVEY.

A. Description of Damage(including Sketch and Photograph):

Scour and Erosion:
-Max. Depth= ft. -Size:
Remaining Debris:
-Quantity: None Few Some Many
-Size : Length= ft. Width= ft.

B. Opinion on Cause of Failure:

C. Estimated Cost of Damage= US $