An Observed-Streambed-Scour Index for Selected Bridges in Southwestern Indiana, 1991

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ABSTRACT

Streambed scour was assessed at 1,338 federal-aid bridges in southwestern Indiana during 1991. The assessments were conducted as part of a 7-year study by the U.S. Geological Survey in cooperation with the Indiana Department of Transportation that will evaluate 5,600 bridge sites throughout the State. Measurements and observations of remnant scour made during low-flow discharges were used to record site conditions. These remnant-scour data were used to develop an observed-streambed-scour index that provides a screening mechanism for ranking existing streambed scour. The observed-streambed-scour ranking values range from 10 (no observed-streambed scour) to 0 (pier[s] with pile[s] exposed). This index is based on the relative integrity of the substructure of each bridge with respect to observed-streambed scour. This observed-streambed-scour index was developed by use of qualitative criteria established with cooperative input from the Indiana Department of Transportation and is intended as a screening tool to rank existing scour conditions. Numerous other factors that have not been included in this indexing scheme need to be considered when evaluations of overall bridge integrity are made.

INTRODUCTION

Streambed scour during periods of flooding is a primary cause of bridge failure. Abrupt changes in channel morphology that result in bridge failure are often symptomatic of an ongoing scour process that may accelerate and slow with the beginning and end of each high-flow event. The Federal Highway Administration (FHWA) defines "total scour" as having three components: degradation, contraction scour, and local scour (Federal Highway Administration, 1991). Degradation is general streambed lowering throughout a reach and can be the result of instream disturbances, such as sand and gravel mining or channelization. Contraction scour usually occurs across all or most of a bridge opening and is common where embankments block a significant part of the floodplain. Local scour often is restricted to small areas of a channel and usually occurs because of increased flow velocities and turbulence around obstructions such as piers, abutments, embankments, or debris piles (Dargahi, 1990). An inadequate knowledge of the factors involved in these scour processes increases the probability of bridges failing, the risk to people who travel across them, and the potential for excessive expenditure of funds to maintain or replace them.

Following the 1967 Silver Bridge failure in Point Pleasant, West Virginia, the U.S. Congress established the Federal Aid Highway Act of 1968, part of which called for the establishment of National Bridge Inspection Standards (NBIS).

After the April 1987 Schoharie Creek Bridge failure in New York (Zembrzuski and Evans, 1989), the National Transportation Safety Board (1988) recommended that the NBIS be modified to require an assessment of instability problems caused by geomorphic processes.

Minimizing high-flow damage to the nation's bridges is a priority, and screening bridges for existing scour problems could help decrease the number of bridge failures (Federal Highway Administration, 1988). During 1990, the U.S. Geological Survey (USGS), in cooperation with the Indiana Department of Transportation (INDOT), began a project to assess streambed scour and stream-channel instability at 5,600 bridges throughout Indiana that were built with or are maintained with some federal funding. One objective of this project was to develop a screening technique to identify bridges that have existing scour problems. This screening process can be used by bridge managers to aid in prioritizing maintenance.

Purpose and Scope

This report presents a qualitatively derived observed-streambed-scour index that can be used to rank bridges according to observed-streambed-scour conditions. This report also documents the scour observed at 1,338 bridges in southwestern Indiana during 1991 and discusses the limitations of the ranking process.

Study Area

During 1991, assessments of streambed scour at bridges were conducted in all southwestern Indiana counties, except the counties of Posey and Warrick. These scour assessments were conducted within an area bounded by Vermillion, Fountain, Montgomery, and Boone Counties to the north, the Ohio River to the south, the Indiana-Illinois State line to the west, and Hendricks, Morgan, Monroe, Lawrence, Orange, and Crawford Counties to the east (fig. 1).

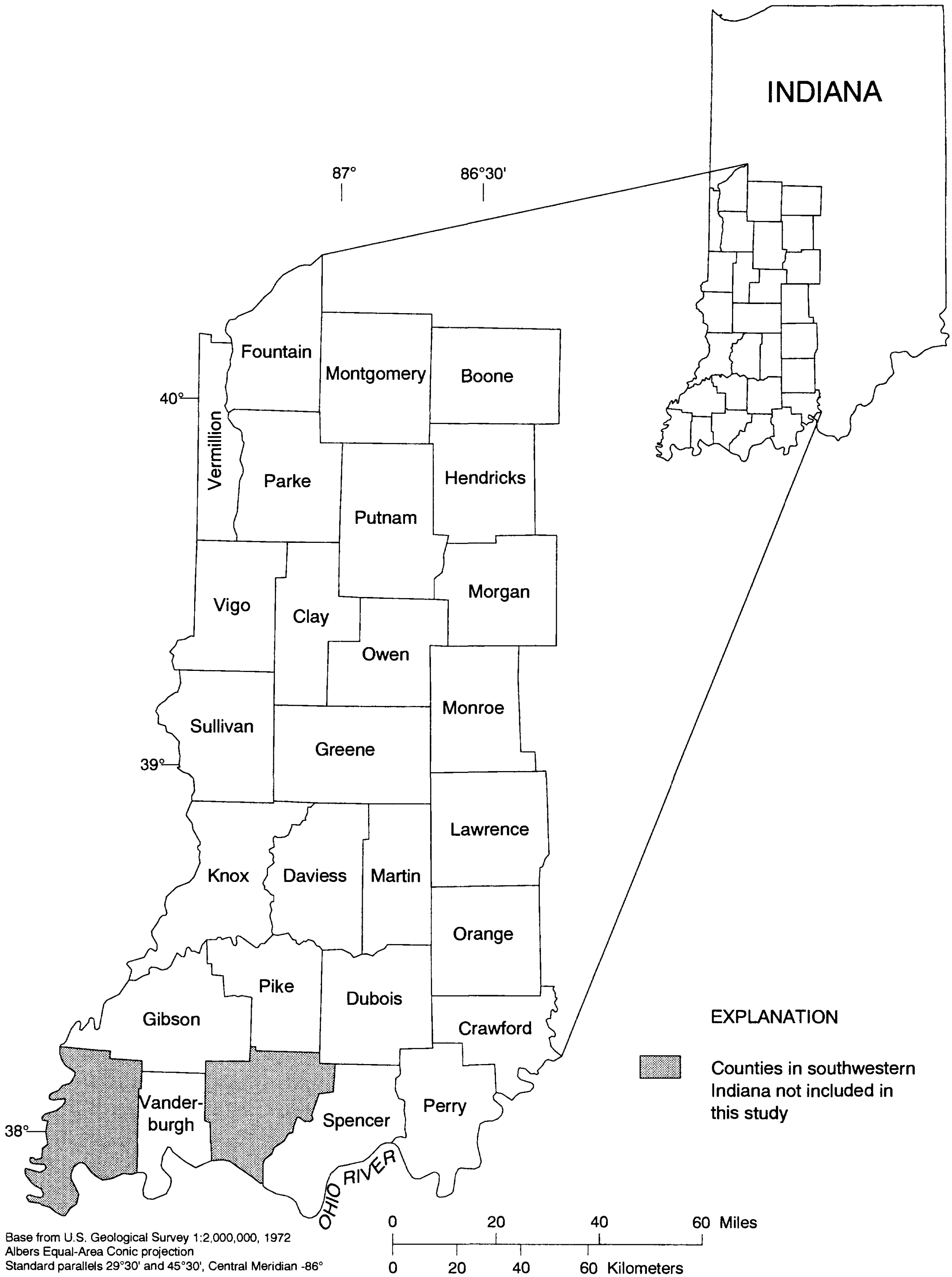
Acknowledgments

Numerous individuals have provided refinements to the data-collection and assessment processes. Specific thanks go to John Pangallo, Indianapolis Department of Public Works (previously with INDOT), and to Steve Toillion, Federal Highway Administration, for their valued assistance.

METHODS USED TO DOCUMENT EXISTING SCOUR

The USGS (Simon and others, 1989) developed a data-collection form for the recording of general geomorphic characteristics of bridge sites and a process for the rating of bridges in terms of observed- and potential streambed scour that is applicable to western Tennessee. On the basis of work by Simon and others (1989), Robinson and Thompson (1993) developed a field form that provides an efficient method for the collection of geomorphic and hydraulic data for streambed-scour assessments at bridges in Indiana.

The collected geomorphic data included high-flow angle of approach, upstream and downstream channel profiles, existence and type of bank erosion, bank heights and angles, percentages of each bank covered by woody vegetation, bed and bank materials, and channel widths. Data also were collected for some factors that affect hydraulic performance, such as vertical separation from streambed to low steel, debris accumulations, the angle at which flow approaches the piers and abutments, and type and location of piers and abutments. Finally, several observations were made and recorded to document any recognized scour—including the location and dimensions of scour holes and any exposure of the footings or piles that support the piers or abutments. Although numerous data were collected in this study, the key elements used to document scour were photographs of each site, a plan-view sketch of each site, and descriptions of existing scour.



Base from U.S. Geological Survey 1:2,000,000, 1972
Albers Equal-Area Conic projection
Standard parallels 29°30' and 45°30', Central Meridian -86°

Figure 1. Map showing the southwestern Indiana study area.

Photographs

A minimum of four photographs were taken at each site. Two of the photographs (one looking upstream from the bridge, the second looking downstream from the bridge) documented channel and floodplain conditions. The third photograph, taken from an upstream vantage point looking downstream at the bridge, was used primarily to illustrate significant obstructions to flow and the alignment of the channel near the bridge. The fourth photograph, taken downstream from the bridge looking upstream at the bridge, was used to document bridge-opening exit conditions. Additional photographs were taken as needed to further document existing problems such as significant scour or large accumulations of debris.

Plan-View Sketch

A plan-view sketch was drawn to illustrate the geometric layout of each site, to note where specific measurements and observations were made, and to record any significant findings not addressed elsewhere on the form. The plan-view sketch included but was not limited to: bank orientations relative to the bridge; flow direction; locations and directions of photographs; and relative positions of any scour countermeasures, accumulations of debris, and all recognized sites of remnant scour.

Descriptions of Existing Scour

The pier and abutment sections of the field form included observations of local scour and footing or piling exposure, or both. These sections of the form provided a record of any scour in direct contact with the bridge substructure. A separate section of the form was used to record the location(s) and approximate dimensions of any scour holes not in direct contact with the bridge substructure.

OBSERVED-STREAMBED-SCOUR INDEX

The observed-streambed-scour index presented in this report was developed through direct conversation with personnel at INDOT. The ordering of the observed-streambed-scour categories in this subjective index was based on INDOT's perception of the relative severity of each observed-streambed-scour category (John Pangallo, INDOT, oral commun., 1993). The index, shown in table 1, ranges from 10 to 0, with the upper end of the scale (for example, ranking values 10 and 9) indicating those bridges with lowest priority for further investigation and the lower end of the scale (for example, ranking values 5 to 0) indicating those bridges that will be given highest priority for further investigation. While the specific categories used in this index may be overly simplistic, the index provides an expeditious means of ranking bridges based on observed-streambed-scour conditions.

Table 1. Observed-streambed-scour index

Observed-streambed-scour categories	Ranking values
No observed-streambed scour	10
Scour hole(s) only	9
Local scour at abutment(s) only	8
Local scour at pier(s) only	7
Local scour at pier(s) and scour hole(s)	6
Blow hole	5
Vertical abutment(s) with footing(s) exposed	4
Sloping abutment(s) with pile(s) exposed	3
Vertical abutment(s) with pile(s) exposed	2
Pier(s) with footing(s) exposed	1
Pier(s) with pile(s) exposed	0

Ranking value 10 is assigned to all sites with "No observed-streambed scour." Ranking value 9 is assigned to sites with "Scour hole(s) only." The term "Scour hole(s)" is used to describe the condition where there is clear evidence that material has been eroded from the bed but where the scour is not in contact with the bridge substructure.

Ranking value 8 is assigned to sites with "Local scour at abutment(s) only." The term "Local scour" is used to describe the condition where scour is in contact with the substructure of a bridge, but no significant exposure of footings or piles exists. "Local scour at pier(s) only," ranking value 7, and "Local scour at pier(s) and scour hole(s)," ranking value 6, refer respectively to increasingly hazardous scour effects.

The category "Blow hole," ranking value 5, refers to extensive failure of both stream banks in the immediate, downstream vicinity of a bridge that may occur when a bridge constitutes a contracted opening for the stream. A site with a blow hole is considered more hazardous to the bridge substructure and the roadway approaches than the previously discussed conditions.

"Vertical abutment(s) with footing(s) exposed," "Sloping abutment(s) with pile(s) exposed," and "Vertical abutment(s) with pile(s) exposed," all pertain exclusively to scour conditions encountered at abutments. The ranking values, 4 to 2 respectively, indicate increasing scour effects.

The remaining two categories pertain exclusively to piers. The category "Pier(s) with footing(s) exposed," ranking value 1, includes exposed pile cap(s) and spread footing(s) without holes underneath them. Because field inspectors had insufficient information to distinguish a pile cap from a spread footing, all sites that had a hole underneath a pile cap or a spread footing were recorded in the "Pier(s) with pile(s) exposed" category. The category "Pier(s) with pile(s) exposed," ranking value 0, represents the most severe scour conditions encountered during the 1991 scour assessments.

Table 1 lists the observed-streambed-scour categories and the corresponding observed-streambed-scour ranking value for each category. For example, with all other factors equal, "Sloping abutment(s) with pile(s) exposed," ranking value 3, is considered to be less severe in terms of observed-streambed scour than "Vertical abutment(s) with pile(s) exposed," ranking value 2. If multiple observed-streambed-scour categories exist at one site, the lowest appropriate ranking value is assigned to that site.

Table 2 shows, by county, the number of bridges in each of the 11 observed-streambed-scour categories. The percentage of bridges for each index category is listed at the bottom of the table. For example, no streambed scour was observed at 53.9 percent of the 1,338 bridges assessed during 1991.

The procedures for recording observed-streambed scour and the resulting observed-streambed-scour index have recognized limitations. For example, most bridges were assessed for remnant streambed scour during low-flow conditions. Assessment of the bridges at low stages allowed for visual inspection and the photographing of scour impacts; however, some scour that may have occurred during higher stages might have been obscured by deposition of sediment prior to site visits. In addition, some of the impacts attributed to scour during site visits may have resulted from processes other than stream/bridge interactions (for example, water draining from the roadway may have eroded embankment material and exposed piles under sloping abutments).

A limitation of the index is the inherent assumption that equivalent effects of scour on an abutment are less threatening to a bridge than are the same effects on a pier. This assumption may not be valid but is based on the concept that the embankments offer some degree of protection or stability to the abutments, whereas the embankments do not offer this same protection to piers.

The observed-streambed-scour index represents just one of the elements used when evaluations of overall bridge integrity are made. The ultimate risk of bridge failure can be more fully determined after hydraulic and hydrologic data, geotechnical information, the structural soundness of a bridge, and traffic use also are evaluated.

SUMMARY

As part of a 7-year study, the USGS during 1991 assessed 1,338 bridges in southwestern Indiana for observed-streambed scour and potential for streambed scour. Analysis of the observed-streambed-scour assessment data resulted in scour categories that were then ranked by their perceived level of severity.

The observed-streambed-scour index developed from this study has ranking values ranging from 10 (no observed-streambed scour) to 0 (pier[s] with pile[s] exposed). This index can be used as a tool for preliminary assessment of scour-related conditions; however, this index is subjective, is based on best professional judgment, and is intended only as an initial screening device. In addition to this index, other factors to consider include hydraulic and hydrologic data, geotechnical information, structural soundness, and traffic use.

Table 2. The number of bridges in each observed-streambed-scour index category resulting from the 1991 scour assessments, listed by county

	Observed-streambed-scour ranking values										
County name	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
Boone	45	8	2	10	6	0	6	0	0	3	0
Clay	24	7	0	0	3	0	3	0	0	2	0
Crawford	22	3	0	1	3	0	5	0	0	2	0
Daviess	8	4	0	3	1	0	1	1	0	2	0
Dubois	32	5	0	4	1	0	8	0	0	5	0
Fountain	20	9	0	3	13	0	5	1	1	3	1
Gibson	34	9	0	3	1	0	4	0	1	1	0
Greene	21	6	1	7	4	0	6	0	0	1	0
Hendricks	44	15	2	6	16	0	8	0	0	0	0
Knox	42	10	1	4	3	0	5	0	1	2	0
Lawrence	23	3	0	3	2	0	3	0	0	4	0
Martin	14	6	0	0	1	0	1	0	0	0	0
Monroe	27	4	0	3	3	0	11	0	0	2	0
Montgomery	39	12	1	4	4	0	6	0	1	4	1
Morgan	48	11	3	8	5	0	9	2	0	5	0
Orange	24	3	0	0	0	0	5	0	1	3	0
Owen	15	4	0	3	2	0	8	1	1	3	0
Parke	25	5	0	2	7	0	12	0	0	2	0
Perry	14	5	0	2	0	0	5	0	1	2	0
Pike	24	7	0	1	1	0	2	1	1	1	1
Putnam	25	6	0	3	9	0	8	1	1	4	0
Spencer	11	1	0	0	2	0	1	0	0	1	0
Sullivan	29	6	1	5	4	0	1	0	1	3	1
Vanderburgh	57	6	0	4	3	0	3	0	1	1	0
Vermillion	12	5	0	6	9	0	6	0	0	1	1
Vigo	42	9	1	9	7	0	6	3	2	9	0
Percentage of Total	53.9	12.7	0.9	7.0	8.2	0.0	10.3	0.7	1.0	4.9	0.4

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