United States
Department of
Agriculture

Forest Service

Forest
Products
Laboratory

National Wood in
Transportation
Information
Center

Research
Note
FPL–RN–0289

In cooperation
with the

United States
Department of
Transportation

Federal
Highway
Administration

Creosote Retention Levels of Timber Highway Bridge Superstructures in Michigan's Lower Peninsula

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Abstract

Environmental concerns about preservative bleeding (or migrating) from timber bridges have increased in recent years. This preliminary study examined the creosote retention levels at six timber highway bridges in Michigan's lower peninsula during the summer of 2000. Several test core samples were removed from the bridge superstructures (four bleeders and two controls) and were evaluated for creosote content in the laboratory. Results from three of the four bleeder bridges indicated high creosote retention levels between 36 and 52 lb/ft^3 (576.7 and 833 kg/m^3) after several years in service.

Keywords: timber, highway, bridge, red pine, creosote, retention, bleeding

August 2003

Wacker, James P.; Crawford, Douglas M.; Eriksson, Merv O. 2003. Creosote retention levels of timber highway bridge superstructures in Michigan's lower peninsula. Res. Note FPL-RN-0289. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 17 p.

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The Forest Products Laboratory is maintained in cooperation with the University of Wisconsin.

Acknowledgments

The authors extend appreciation to the following people for their valuable contributions to this project: Dan Sikarskie and Roger Rasmussen (retired) of the Huron Pines Resource Conservation and Development Council (Grayling, Michigan) for coordination of fieldwork and assistance with gathering initial treatment process information; Dan Foster and Stan Lebow of the USDA Forest Service, Forest Products Laboratory, for technical assistance with fieldwork and laboratory analysis procedures; and Carlito Calil, Jr., of the University of Sao Paulo at Sao Carlos (Brazil) for assistance with fieldwork. We also acknowledge the assistance of the following organizations for permitting access to their bridges and providing background treatment documents for this study: Missaukee County Road Commission, Alcona County Road Commission, Crawford County Road Commission, Otsego County Road Commission, and the U.S. Fish and Wildlife Service—Shiawassee National Wildlife Refuge.

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Introduction

Creosote has been used as a wood preservative for nearly 200 years. The use of creosote as a wood preservative in the United States began around 1870 when a pressure-treatment plant was constructed in Pascagoula, Mississippi, to produce railroad ties (Webb 1976). By the 1920s, creosote was the treatment of choice for the railroad industry and continues to be so today (Gjovik and others 1980). In the United States, approximately 15% of the total volume of wood treated with preservatives is treated with creosote (AWPA 1997). Creosote is used extensively within the United States for treatment of construction timbers, poles, and posts.

For highway bridges, creosote has been widely used since the 1940s. However, one problem associated with the use of creosote preservatives is the tendency to exude, or "bleed," from some treated products, producing an oily or tar-covered surface "crud" that can cause handling problems and has increased public concern about effects on the environment (Crawford and others 2000). In the past decade, rising concerns about bleeding of preservatives from highway bridges, and the potential effects on the environment, have resulted in preservative bans by some state environmental protection agencies. Recent efforts in the State of Michigan have resulted in revisions to Department of Transportation specifications for treated timber highway bridges and development of best management practices (Pilon 2002).

The Michigan Timber Bridge Committee (Michigan DNR 1995) contacted the USDA Forest Service, National Wood In Transportation Information Center (NWITIC), to report complaints regarding excessive creosote bleeding at bridge sites that were partially funded through the Wood In Transportation (WIT) program administered by the USDA Forest Service. NWITIC contacted the USDA Forest Service, Forest Products Laboratory (FPL), for technical assistance due to its ongoing field monitoring research activities covering timber highway bridges and wood preservatives. This report, a cooperative effort between the Michigan Timber Bridge Committee, NWITIC, and FPL, summarizes the findings of a preliminary study to assess the in-service creosote retention levels of several timber highway bridge superstructures at various locations in Michigan's lower peninsula.

Background

Previous research to study field bridges and other exposed treated wood structures for preservative retention is limited. However, a cursory review of technical publications related to creosote-treated highway bridges is presented.

Highway Bridge Applications

A thorough description of wood preservatives and how they are typically used for highway bridges and structures is given in Ritter (1992). Included are specific recommendations for using creosote with sawn lumber and glulam materials, along with suggestions for improving the cleanliness of oil-type preservatives in service.

As part of its National Bridge Monitoring Program, FPL has evaluated several creosote-treated highway bridges in the past 13 years (Hislop 1998; Hislop and Ritter 1996; Kainz 1998; Kainz and others 1996, 2001; Lee and others 1997; Ritter and others 1995a, 1996a,b; Wacker and Ritter 1995; Wacker and others 1997, 1998a,b). These field studies primarily concentrated on structural performance characteristics of the bridges. During the monitoring, condition assessments included intensive visual inspections of the preservative-treated wood components, but no core sampling was done.

Potential Environmental Effects of Preservatives

Webb (1976) reviewed research studies that show how the aquatic environment is affected by the presence of creosote-treated piles and bulkheads. Included were studies to measure water quality and toxicity to birds and fish.

Webb and Gjovik (1988) include a review of information concerning treated wood products and a cursory review of literature pertaining to potential preservative exposure to the environment and its effect on human health.

Brooks (2000) investigated six different bridge sites treated with chromated copper arsenate (CCA), creosote, and pentachlorophenol (Penta) to measure the concentration of these preservatives lost to adjacent environments and the biological response to these preservatives.

The Forest Products Laboratory (2000) investigated a wetland boardwalk treated with several different waterborne preservatives to measure the amount of preservative leaching into the environment and any effect on the aquatic plant and animal life.

Lebow and Tippie (2001) prepared a guide for minimizing the effect of preservative-treated wood in sensitive environments. This guide provides procedures and techniques to prevent in-service bleeding problems.

Creosote Treatment Industry Standards and Guidelines

The American Wood Preservers' Association (AWPA) develops and maintains industry standards for various wood preservatives used to treat wood products.

- AWPA standard P1/P13 (AWPA 1995) is the standard for creosote preservative used in land, fresh water, and marine (coastal water) applications.
- AWPA standard C14 (AWPA 1999a) covers wood used in highway construction projects, such as bridges.
- AWPA standard C28 (AWPA 1999b) covers preservative treatment of structural glued-laminated timber (glulam) members.
- AWPA standard M20 presents guidelines for minimizing oil-type preservative migration, or preservative bleeding problems.

The Western Wood Preservers Institute and the Canadian Institute of Treated Wood recently published a guide for using treated wood in aquatic environments (WWPI 1996).

Creosote Preservative

A comprehensive resource on wood preservatives including information on creosote is presented in Cassens and others (1995).

Recent efforts (Crawford and others 2000) are focusing on a cleaner creosote, referred to as pigment-emulsified creosote, leading to treated products with cleaner surfaces that are less likely to bleed in service.

Objective and Scope

The objective of this preliminary study was to assess the in-service retention of creosote in several timber highway bridge superstructures. A review of available information regarding initial preservative treatment conditions was also conducted for each timber bridge.

The assessment involved the removal of several boring samples at each bridge site and a laboratory analysis using assay test methods. A total of six timber bridges located in Michigan's lower peninsula were included in this study (Table 1) based upon the recommendation of the Michigan Timber Bridge Committee. Four of the six bridges were classified as "bleeder" bridges due to creosote visibly bleeding from the bridge superstructure. Two of the six bridges were classified as control bridges due to very limited creosote bleeding and dry surface conditions. The age of the bridges varied from 1 year (La Chance and Houlihan) to 10 years. Five of the six bridges were constructed with glued-laminated (glulam) timber components. Two of the bleeder bridges and both of the control bridges were made with red pine lumber or glulam components for the superstructure. Other species used in the bridge superstructures included Douglas-fir, southern pine, and pin oak.

Except for the La Chance bridge, all the bridges had a stress-laminated deck configuration. However, the deck truss members at the La Chance bridge were transversely post-tensioned in a similar fashion to stress-laminating. The general configuration of stress-laminated decks is shown in Figure 1. For stress-laminated bridges, high strength steel bars are inserted through prebored holes, and when tension is applied to these bars, the wood laminations are compressed together to form the deck superstructure. The treated wood laminations, whether sawn lumber or glulam, typically undergo compression stresses in the range of 100 to 120 lb/in^2 (1.6 to 1.9 g/m^3) during initial bar tensioning at construction and in the range of 50 to 80 lb/in^2 (0.8 to 1.3 g/m^3) during typical service conditions.

Table 1—Creosote-treated bridge sites investigated in Michigan's lower peninsula

County	Bridge name	Superstructure type	Year built	Superstructure materials	Wood species
		Bleeder bridges			
Missaukee	La Chance	Deck truss[a]	1998	Glulam	Douglas-fir (truss) Red pine (deck)
Alcona	Cruzen	Stress-laminated deck	1995	Glulam	Red pine
Crawford	Cameron	Stress-laminate box-section	1995	Glulam and sawn lumber	So. pine glulam (web) Pin oak sawn (flange)
Saginaw	Houlihan[b]	Stress-laminated deck	1999	Glulam	So. pine
		Control bridges			
Alcona	Barlow	Stress-laminated deck	1997	Glulam	Red pine
Otsego	Old Vanderbilt	Stress-laminated deck	1989	Sawn lumber	Red pine

[a] Truss members are also compressed together at diaphragms with high strength tension bars similar to stress-laminated decks.
[b] Owned by the U.S. Fish and Wildlife Service and located within the Shiawassee National Wildlife Refuge.

Methods

Fieldwork was conducted during the summer of 2000 and included visual inspections, core sampling, and moisture content readings from the bridge superstructure components. Work was completed at the La Chance, Cruzen, Barlow, and Houlihan bridge sites in July and at the Cameron and Old Vanderbilt bridge sites in September.

Visual inspections focused on the condition of the treated wood components and photographic documentation of the preservative surface residues or any evidence of preservative bleeding. Also, the general condition of the asphalt wearing surface was assessed. Visual inspections followed previously established field procedures for inspecting stress-laminated bridges in service (Ritter and others 1995b).

Core samples were removed from creosote-treated members located in the superstructure of each bridge. Each core was removed from the bridge using a ⅜-in.- (9.5-mm-) diameter increment borer in combination with a hand drill (Fig. 2). Bridge drawings with approximate locations of the core samples are included in the Appendix. At each core sample location, three cores (approximately 2 to 3 in. (50.8 to 76.2 mm) long) were removed from the same deck lamination (or truss member) and combined into a glass specimen vial during transit. Treated hardwood dowel plugs were hammered into the sample holes. Core sampling procedures followed the American Wood-Preservers' Association Standard M2 (AWPA 2000a).

Moisture content data were collected from four bridges at various locations on the underside of the bridge superstructure with an electrical-resistance type meter (model RC–1D, Delmhorst Instrument Company, Towaco, New Jersey) and 3-in.- (76.2-mm-) long insulated pin probes. Raw readings were typically collected at 1-, 2-, and 3-in. (25.4-, 50.8-, and 76.2-mm) pin probe penetration depths. Moisture content data collection procedures followed American Standard for Testing and Materials (ASTM) Standard D4444–92 (ASTM 2000). Temperature and wood species corrections to raw field readings were performed as required (Pfaff and Garrahan 1984).

Laboratory Methods

Laboratory evaluations of the core samples removed from the bridges were conducted at FPL shortly after fieldwork was completed. Each of the core samples was trimmed in length (maximum of 1 in. (25.4 mm) for sawn lumber and 0.6 in. (15.2 mm) for glulam) to isolate the outer (exposed) end for laboratory testing. Laboratory tests to measure the creosote content in the trimmed core samples were conducted in accordance with AWPA Standard A6 (AWPA 1997).

Review of Available Treatment Information

All available information regarding the initial treatment conditions of the bridge superstructure wood components was requested from the various bridge owners. This information was reviewed to possibly determine the root cause for the preservative bleeding from the bridges.

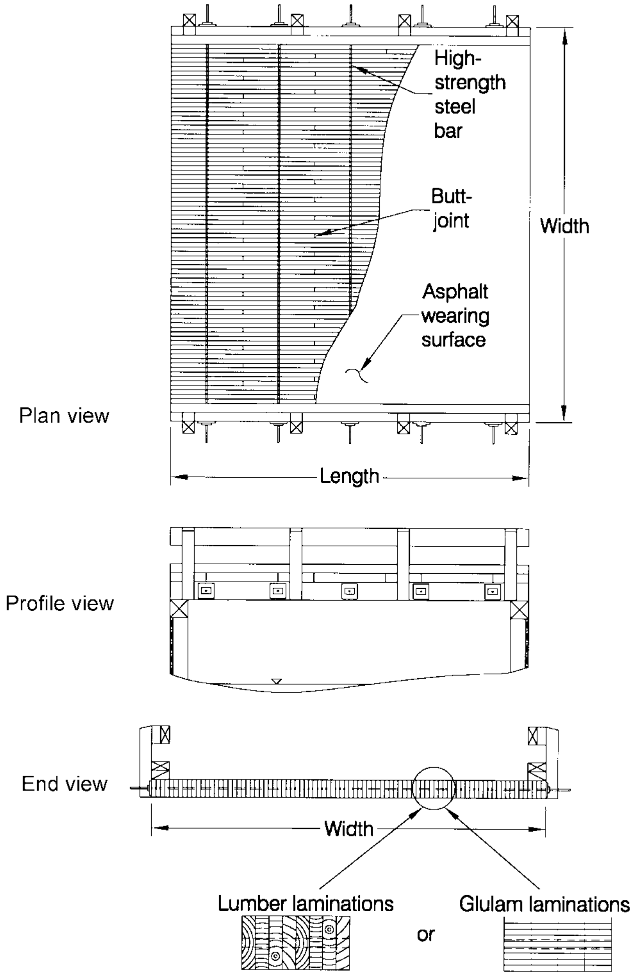

Figure 1—General configuration of a stress-laminated deck bridge superstructure.

Figure 2—Removal of core samples from the La Chance bridge using an increment borer and hand drill.

Results and Discussion

Visual Inspections

The bridge site with the most visibly active creosote bleeding was La Chance bridge superstructure in Missaukee County (Fig. 3). The La Chance bridge deck members (red pine glulam) seemed to be the primary source of creosote preservative bleeding, with additional residue from the asphalt paving membrane also present. The underlying truss members at La Chance did not seem to be actively bleeding but were extensively coated on the top sides with creosote "crud" from the deck above.

Creosote bleeding was extensive on the deck underside and along the edge beams at the Cruzen bridge superstructure in Alcona County (Fig. 4). The glulam (web) beams were actively bleeding at the bridge underside and along the edge beams at the Cameron bridge superstructure in Crawford County (Fig. 5). Several of the glulam beams in the middle span appeared to have an oily residue on the deck underside of the Houlihan bridge superstructure within the Shiawassee National Wildlife Refuge (Fig. 6). The control bridges, Barlow in Alcona County (Fig. 7) and Old Vanderbilt in Otsego County (Fig. 8), had minimal amounts of creosote crud on the exposed wood members and were not visibly bleeding.

At the Cruzen and Cameron sites, the creosote wood preservative appeared to have migrated upward through the asphalt wearing surface (Fig. 9). At the Cameron bridge, the creosote wood preservative migrated into the asphalt wearing surface only at the glulam web locations. This is especially apparent in the summer months and has caused concerns about vehicle traction. At the La Chance bridge, there were no visible signs of preservative migration (Fig. 10). However, a waterproof paving membrane had been used that was not compatible with the creosote wood preservative or the asphalt mixture, causing the membrane to liquefy when the hot-mix asphalt was applied. The resulting pavement membrane residue was observed leaking through the transverse deck at the panel butt-joints. Similar problems with creosote wood preservatives and pavement membranes have also been reported (Eriksson 2002, Eriksson and others 2003). Future studies should examine this interaction between creosote preservatives, paving membranes, and the asphalt pavement layer.

Moisture Content

A summary of the moisture content data is presented in Table 2. The moisture content values ranged between 12 and 30%, with a few noted exceptions. At most locations, the 2- and 3-in.- (50.8- and 76.2-mm-) deep moisture content values were slightly higher than the 1-in.- (25.4-mm-) deep values. For glulam components in Michigan's climate, we typically expect relatively low (less than 15%) moisture

Figure 3—La Chance bridge in Missaukee County.

Figure 4—Cruzen bridge in Alcona County.

Figure 5—Cameron bridge in Crawford County.

Figure 6—Houlihan bridge in Shiawassee National Wildlife Refuge.

Figure 7—Barlow bridge in Alcona County.

Figure 8—Old Vanderbilt bridge in Otsego County.

Figure 9—Creosote preservative visibly migrating upward through the asphalt wearing surface at the (a) Cruzen and (b) Cameron bridges.

Figure 10—The La Chance bridge showing the asphalt wearing surface condition.

content shortly after installation with gradual increases during service life. The moisture content values for the glulam bridge superstructures at Cruzen, Cameron (web only), and Barlow were generally below 20% as expected. For sawn lumber components in Michigan's climate, we typically expect somewhat higher (more than 20%) moisture content near installation with gradual decreases during service life. And the moisture content values for the sawn lumber bridge superstructures at Cameron (flange only) and Old Vanderbilt were all above 19% as expected. The moisture content values near and above fiber saturation for the lam 6 and lam 81 locations (Table 2) at Old Vanderbilt bridge are attributed to their proximity to the curb and scupper zone where moisture typically accumulates near the bridge deck edges. Most of the measured moisture contents were near the expected long-term equilibrium value of approximately 18% to 20% for timber bridges in the northern United States (McCutcheon and others 1986).

Core Sampling for Creosote Retention

Table 3 presents a summary of the measured creosote retention levels for each bridge. The Appendix gives additional information and specific locations of core samples.

The highest creosote retention level, 52.2 lb/ft^3 (836.2 kg/m^3), was measured at the Cruzen bridge. The creosote retention levels at the La Chance, Barlow, and Houlihan bridges were within the range of 35 to 46 lb/ft^3 (560.7 to 736.9 kg/m^3). The creosote retention levels at the Cameron bridge were 5.1 lb/ft^3 (81.7 kg/m^3) (sawn lumber flanges) and 12.5 lb/ft^3 (200.2 kg/m^3) (glulam webs), and at the Old Vanderbilt bridge, it was 13.3 lb/ft^3 (213 kg/m^3). The very low retention of the lumber flanges at the Cameron bridge may reflect the low permeability of the pin oak species. In general, most glulam members had significantly higher creosote preservative retention levels than the minimum required AWPA (C28) preservative retention level. The exception to this trend was the Cameron bridge (glulam webs) with 12.5 lb/ft^3 (200.2 kg/m^3) creosote retention. The 46.2-lb/ft^3 (740.1-kg/m^3) creosote retention level at the Barlow (control) bridge was somewhat confusing because there was very little visible creosote preservative bleeding and the superstructure components were post-treatment cleaned.

These results may indicate that some glulam bridge components are not being pressure-treated to the lower target retention levels (AWPA C28) and that some treating facilities may not follow (AWPA M20) guidelines for minimizing oil-type wood preservative migration. Glulam members are more susceptible to high preservative retention levels during pressure treatment because of the low moisture content required during the adhesive bonding fabrication process and the higher percentage of sapwood compared with that in sawn lumber. Therefore, post-treatment processes for glulam components, including steam cleaning and a final vacuum, need more emphasis in highway bridge related codes and standards. Standard specifications for treated timber bridges included in the American Association of State Highway

Table 2—Summary of moisture content measurements from bridge superstructures[a]

		Moisture content (%) at pin penetration[c]		
Bridge name	Location of reading[b]	1 in. (25.4 mm)	2 in. (50.8 mm)	3 in. (76.2 mm)
Cruzen	Beam 1	17	16	19
	Beam 2	13	15	19
Cameron	Web beam 1	15	18	20
	Flange 2	28	33	31
	Web beam 3	20	20	21
Barlow	Beam 3	12	15	18
	Beam 5	13	14	15
Old Vanderbilt	Lam 6	19	42	42
	Lam 28	19	20	21
	Lam 46	19	20	21
	Lam 64	21	23	23
	Lam 81	25	28	27

[a] Two bridges, La Chance and Houlihan, did not have moisture content measurements taken.
[b] Beam or lamination (lam) numbering starts at upstream edge of superstructure.
[c] Shaded moisture content values are out of reliable range of values.

Table 3—Creosote retention levels based on laboratory analysis of core samples removed from bridges

Bridge name	No. of samples and location[a]	Average creosote retention[b] (lb/ft^3 (kg/m^3))	Coefficient of variation (%)
		Bleeder bridges	
La Chance	8 from glulam deck	35.8 (573.5)	9.0
	12 from glulam truss	37.3 (597.5)	8.2
Cruzen	12 from glulam deck	52.2 (836.2)	14.5
Cameron	8 from lumber flange	5.1 (81.7)	41.2
	9 from glulam web	12.5 (200.2)	50.3
Houlihan	4 from glulam deck	41.1 (658.4)	7.8
		Control bridges	
Barlow	7 from glulam deck	46.2 (740.1)	25.2
Old Vanderbilt	5 from lumber deck	13.3 (213.1)	16.3

[a] See Figures 11 to 16 in Appendix for approximate locations.
[b] Three separate cores were removed at each sampling location and combined for laboratory analysis.

Transportation Officials (AASHTO) may need to be revised (AASHTO 2002). Additional studies may be needed to optimize treatment specifications for glulam components made from alternative species. These specifications would be complementary to those already included in AWPA C28.

Lastly, the high compressive stress continually applied to the deck laminations in a stress-laminated bridge (five of the six bridges are stress-laminated) may have contributed to the creosote bleeding problems. More bleeding was noticeable at the lamination interfaces and may indicate a compression-related problem. Additional studies are needed to determine if the compressive stresses are magnifying creosote preservative bleeding problems.

Review of Available Treatment Information

The limited background information that was available about the initial treatment processing conditions is summarized in Table 4. All superstructure wood components were pressure-treated using an empty cell (rueping) process. To refrain from using company names, treatment plants were designated as A, B, and C. Treatment plant B was reported as the treatment facility for all the glulam components in the bridge superstructures, with the exception of the La Chance (Douglas-fir) truss members, and this may have been a contributing factor to the creosote preservative bleeding. In the future, more detailed information about the initial treatment processing conditions needs to be routinely recorded in treatment certificates or contract specifications for timber highway bridges.

Summary and Recommendations

In the summer of 2000, six creosote-treated timber bridge superstructures were visually inspected, sample cores were removed, and moisture contents were measured in an attempt to solve several reported cases of excessive creosote bleeding at various bridge sites.

At the four bleeder bridges, both horizontal and vertical member surfaces were covered with preservative residue, or crud. Those surfaces with exposure to direct sunlight were covered with a thick layer of crud.

Residual creosote retention levels ranged between 5.1 and 52.2 lb/ft^3 (81.7 and 836.2 kg/m^3) with glulam members having significantly higher amounts than sawn lumber. All glulam bridge components (except the Douglas-fir glulam truss members at La Chance) were treated by the same treatment facility. Further examination of preservative treatment cycles might be useful in preventing a recurrence of excessive in-service creosote bleeding.

Table 4—Summary of treatment processing conditions for each bridge superstructure

Bridge name	Treatment plant	Pressure and temperature	Post-treatment heat/cleaning	Post-treatment vacuum (gage pressure)
		Bleeder bridges		
La Chance	A (truss)	150 lb/in^2 and 212°F (1 GPa and 100°C)	None performed[a]	22 inHg (74.5 MPa)
	B (deck)	150 lb/in^2 and 212°F (1 GPa and 100°C)	None performed	22 inHg (74.5 MPa)
Cruzen	B	Data not provided[b]	Data not provided	Data not provided
Cameron	Unknown	Data not provided	Data not provided	Data not provided
Houlihan	B	Data not provided	Data not provided	Data not provided
		Control bridges		
Barlow	B	No pressure listed and 203°F (95°C) Avg.	2 h at 200°F (93°C)	22 inHg (74.5 MPa) for 5 h
Old Vanderbilt	C	Data not provided	Data not provided	Data not provided

[a] Not indicated on treatment certification form.
[b] Treatment certification forms not available.

Definitive conclusions regarding the significance of the measured creosote retention levels are difficult because it is difficult to quantify preservative losses and migration while in service. Additional field investigations, including monitoring of field structures (beginning at installation), are needed to determine causes for the creosote bleeding.

It is strongly recommended that the information included in WWPI (1996) and AWPA (2000b) is incorporated into future editions of the AASHTO standard specifications and material specifications (AASHTO 2002). Post-treatment cleaning procedures (vacuum, steam, etc.) may be extremely important. Revision of AWPA C28 may be warranted to further optimize the creosote pressure-treatment process with respect to glulam members made with alternative wood species.

The effects of high compressive (long-term) stress imposed on the deck laminations due to stress-laminating needs further study to determine if it leads to increased preservative bleeding.

The interaction between creosote preservatives, paving membranes, and asphalt wearing surfaces needs further study to determine causes of membrane disintegration and creosote preservative migration upward through the asphalt pavement layer.

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Appendix

La Chance Bridge Inspection Report

Inspection Date: July 11, 2000

Bridge Location: Missaukee County, MI (Lake Township)

Stream Crossing: Clam River

Years of service: 2

Bridge Dimensions: One span, 79 ft (24.1 m) long, 33 ft (10.1 m) wide, two lanes

Superstructure Type: Deck truss (truss members: glulam Douglas-fir, deck members: glulam red pine)

Wearing Surface Type:

Pavement: Asphalt

Membrane: MEL-DEC brand waterproof

Comments: The deck members were actively bleeding creosote and covering the truss members. A temporary collection platform to prevent the creosote from entering the waterway was constructed by the county. The rubberized asphalt paving membrane appears to have contributed to the problem at this site. The paving membrane melted when asphalt was placed on the deck and has since dripped onto the underlying truss members and into the stream.

Core Samples Taken: Twelve from truss members (taken from the first truss cell adjacent to the south abutment), eight from deck members (taken from the underside of the deck near the south abutment) (Fig. 11).

Cruzen Bridge Inspection Report

Inspection Date: July 12, 2000

Bridge Location: Alcona County, MI (Mikado Township)

Stream Crossing: Roy Creek

Years of service: 5

Bridge Dimensions: One span, 42 ft (12.8 m) long, 32 ft (9.8 m) wide, two lanes

Superstructure Type: Stress-laminated deck (deck members: red pine and southern pine glulam)

Wearing Surface Type:

Pavement: Asphalt

Membrane: None

Comments: Active bleeding from the deck members was visible, and the preservative had migrated upward through the asphalt layer causing slippery conditions for motorists.

Core Samples Taken: Twelve (taken from the deck underside adjacent to the south abutment) (Fig. 12).

Cameron Bridge Inspection Report

Inspection Date: September 19, 2000

Bridge Location: Crawford County, MI (Frederic Township)

Stream Crossing: Manistee River

Years or service: 5

Bridge Dimensions: Two spans, 86 ft (26.2 m) long, 32 ft (9.8 m) wide, two lanes

Superstructure Type: Stress-laminated box section (web members: glulam southern pine beams, flange members: northern pin oak sawn lumber)

Wearing Surface Type:

Pavement: Asphalt

Membrane: Preformed waterproof

Comments: Active bleeding was visible on the (southern pine) glulam webs but not so apparent at the sawn lumber flanges (pin oak). Also preservative migration was observed from web members into the overlying asphalt layer and was visible topside.

Core Samples Taken: Nine from web members, eight from flange members (taken from the superstructure underside about 10 ft (3.1 m) from the west abutment) (Fig. 13).

Houlihan Bridge Inspection Report

Inspection Date: September 20, 2000

Bridge Location: Shiawassee National Wildlife Refuge, Saginaw County, MI

Stream Crossing: Birch Run Drain

Years of service: 1

Bridge Dimensions: Three spans (32, 45, and 32 ft (9.8, 13.7, and 9.8 m) long), 26 ft (7.9 m) wide, two lanes

Superstructure Type: Stress-laminated deck (deck members: glulam red pine)

Wearing Surface Type:

Pavement: Timber plank

Membrane: None

Comments: Bleeding of creosote at several glulam deck beams (at the middle span only) into the sensitive waterways of the national wildlife refuge was of concern because of stagnant water conditions under the bridge.

Core Samples Taken: Four (taken at topside of middle span only) (Fig. 14).

Barlow Bridge Inspection Report

Inspection Date: July 12, 2000

Bridge Location: Alcona County, MI (Harrisville/Guston Township)

Stream Crossing: Van Etten Creek

Years of service: 3

Bridge Dimensions: One span, 36 ft (11 m) long, 28 ft (8.5 m) wide, two lanes

Superstructure Type: Stress-laminated deck (deck members: glulam red pine/southern pine)

Wearing Surface Type:

Pavement: Asphalt

Membrane: unknown

Comments: No active bleeding observed at this site. Only minor staining visible on the riprap near the abutments.

Core Samples Taken: seven (taken from deck underside near midspan) (Fig. 15).

Old Vanderbilt Bridge Inspection Report

Inspection Date: September 19, 2000

Bridge Location: Otsego County, MI (Corwith Township)

Stream Crossing: Sturgeon River

Years of service: 11

Bridge Dimensions: two spans, 40 ft (12.2 m) long, 26 ft (7.9 m) wide, two lanes

Superstructure Type: Stress-laminated deck (deck members: red pine dimension lumber)

Wearing Surface Type:

Pavement: Asphalt

Membrane: None

Comments: Wood members appeared dry with no surface residues.

Core Samples Taken: five (taken from the deck underside of the southernmost span, near centerspan) (Fig. 16).

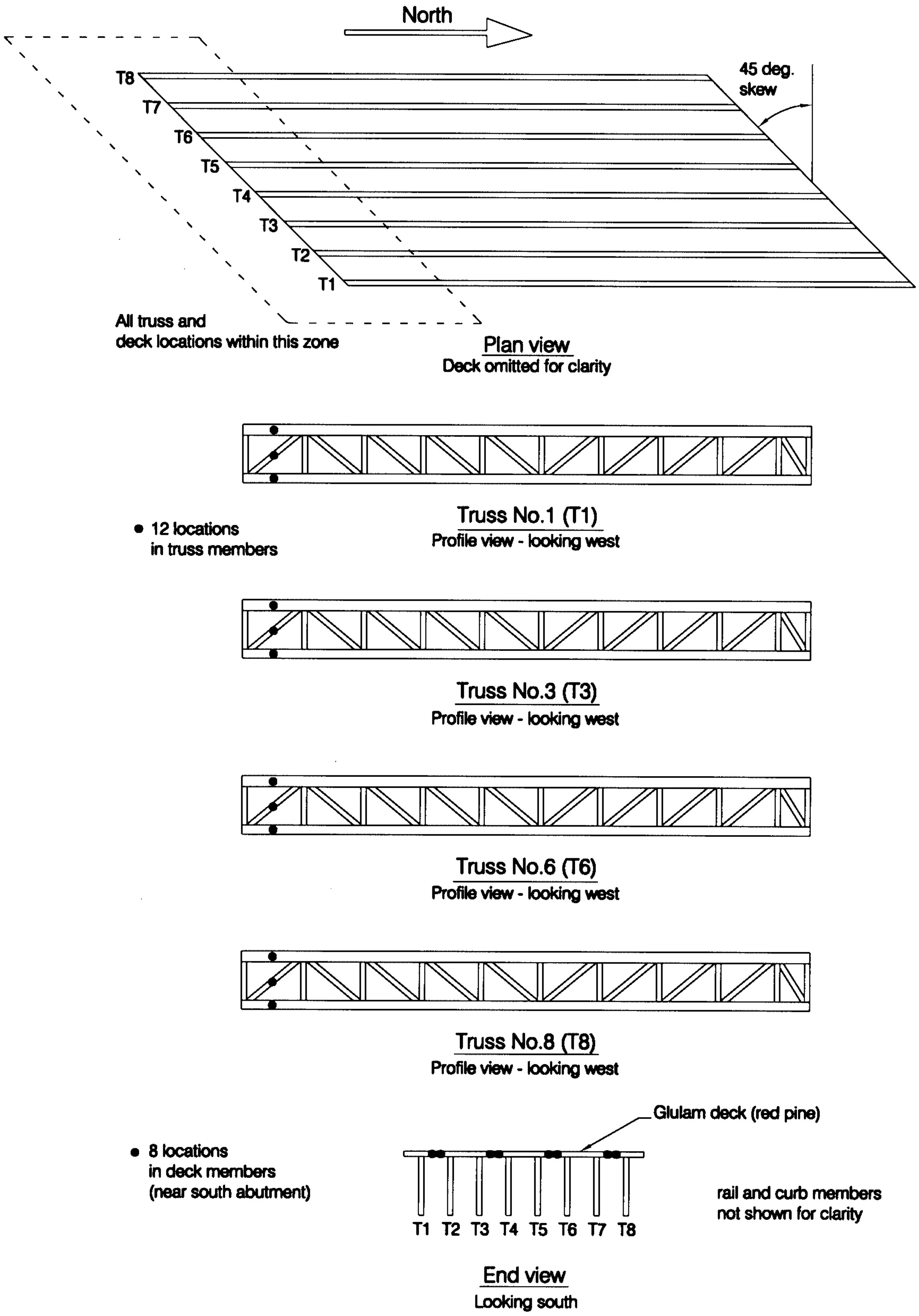

Figure 11—Core sample locations for the La Chance bridge (Missaukee County).

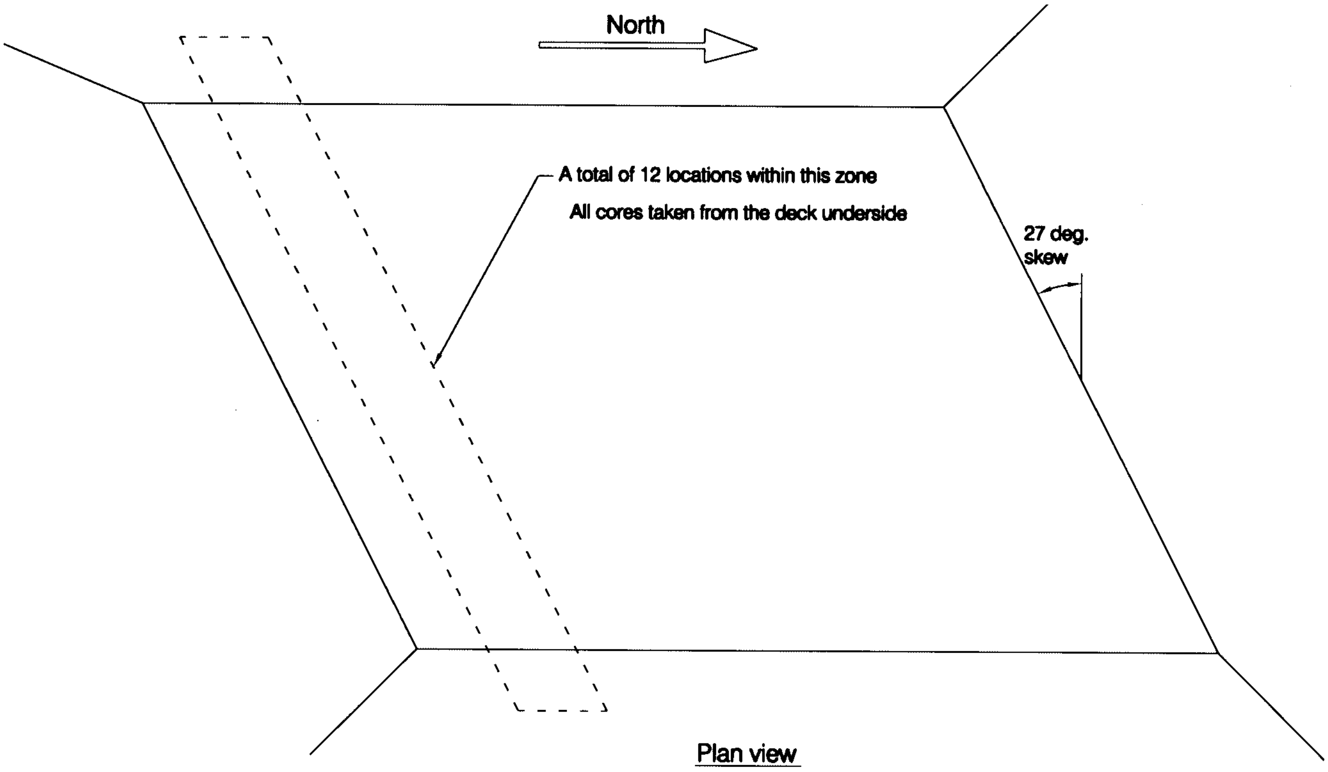

Figure 12—Core sample locations for the Cruzen bridge (Alcona County).

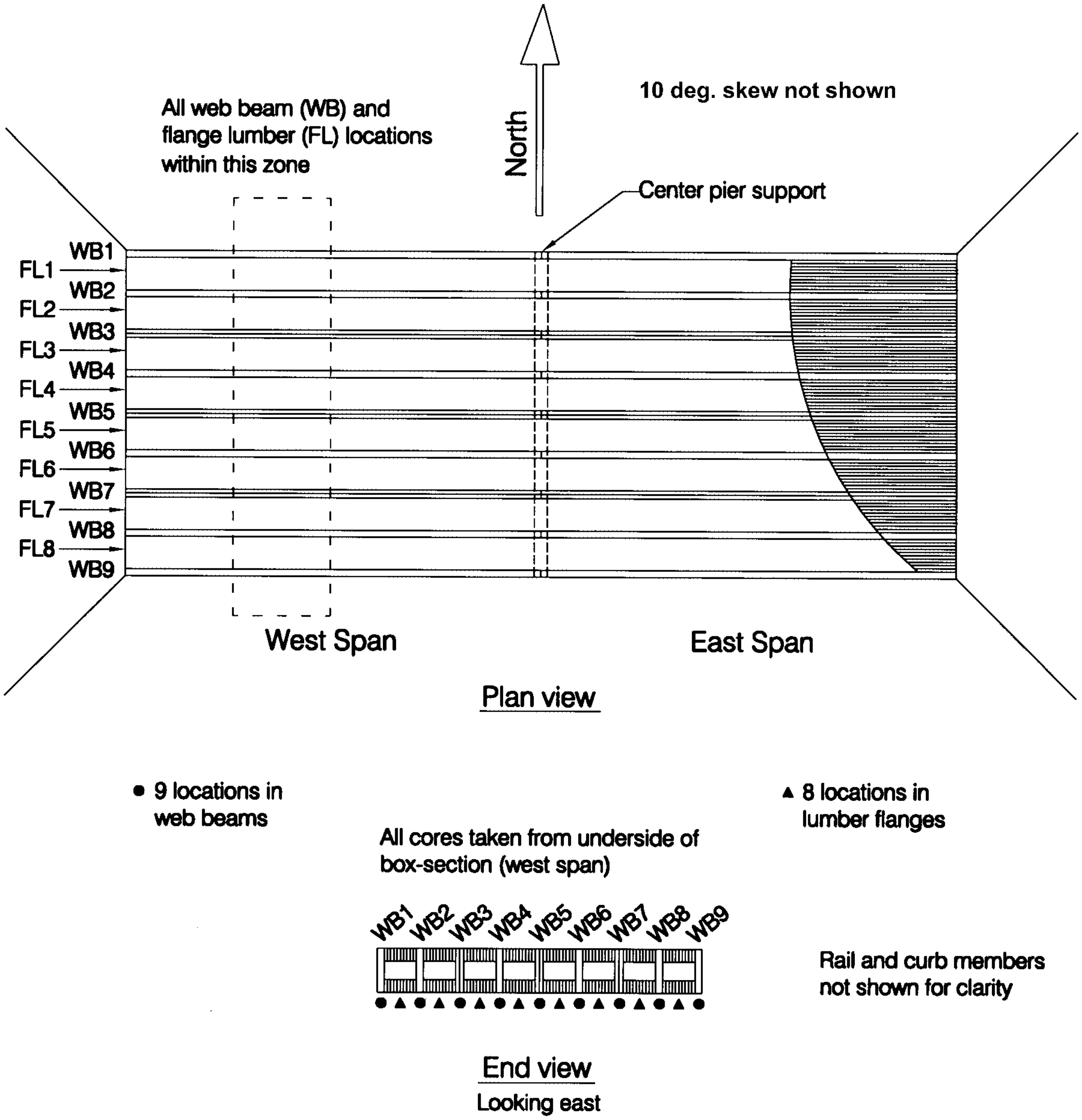

Figure 13—Core sample locations for the Cameron bridge (Crawford County).

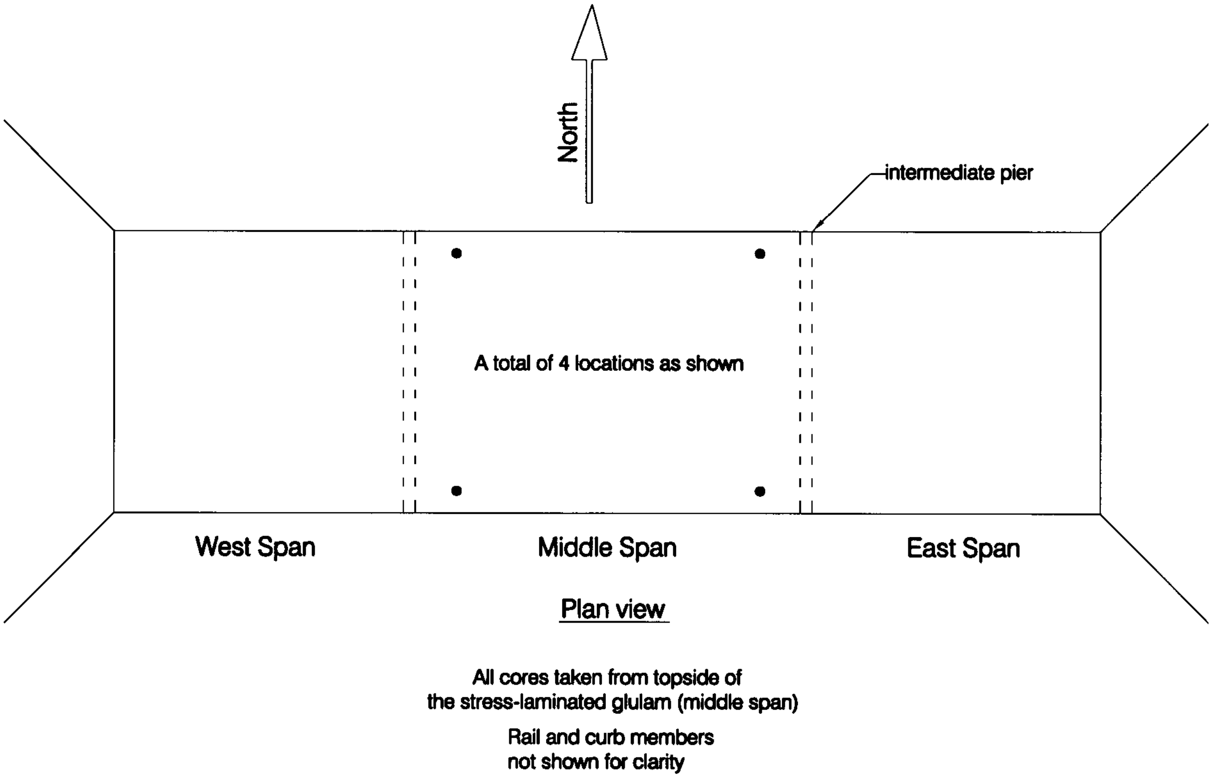

Figure 14—Core sample locations for the Houlihan bridge (Shiawassee National Wildlife Refuge).

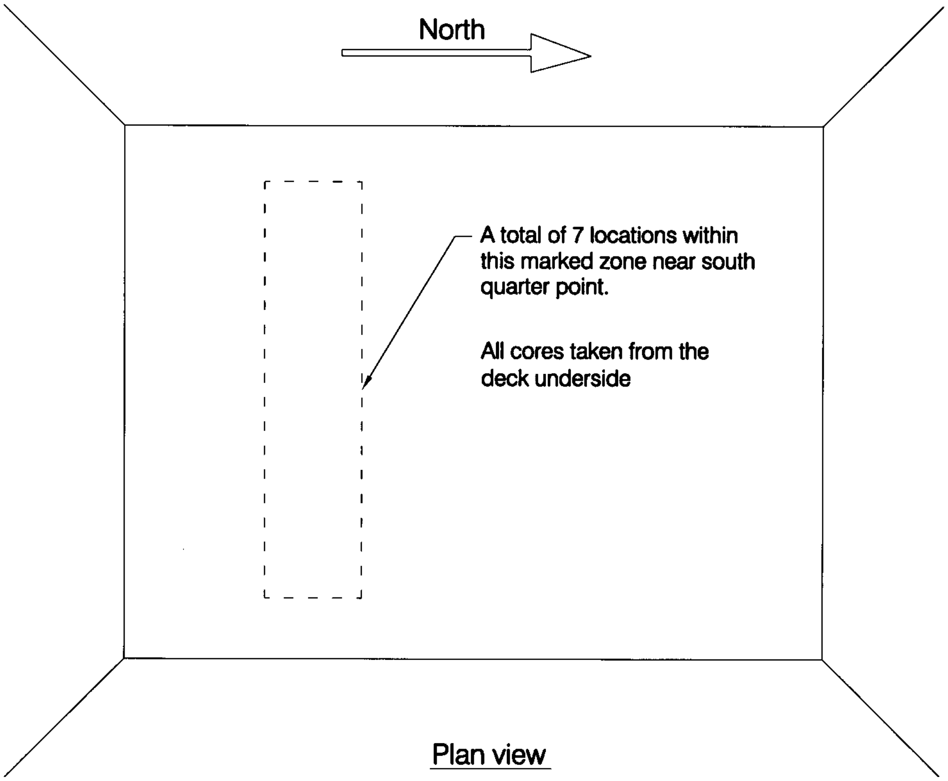

Figure 15—Core sample locations for the Barlow bridge (Alcona County).

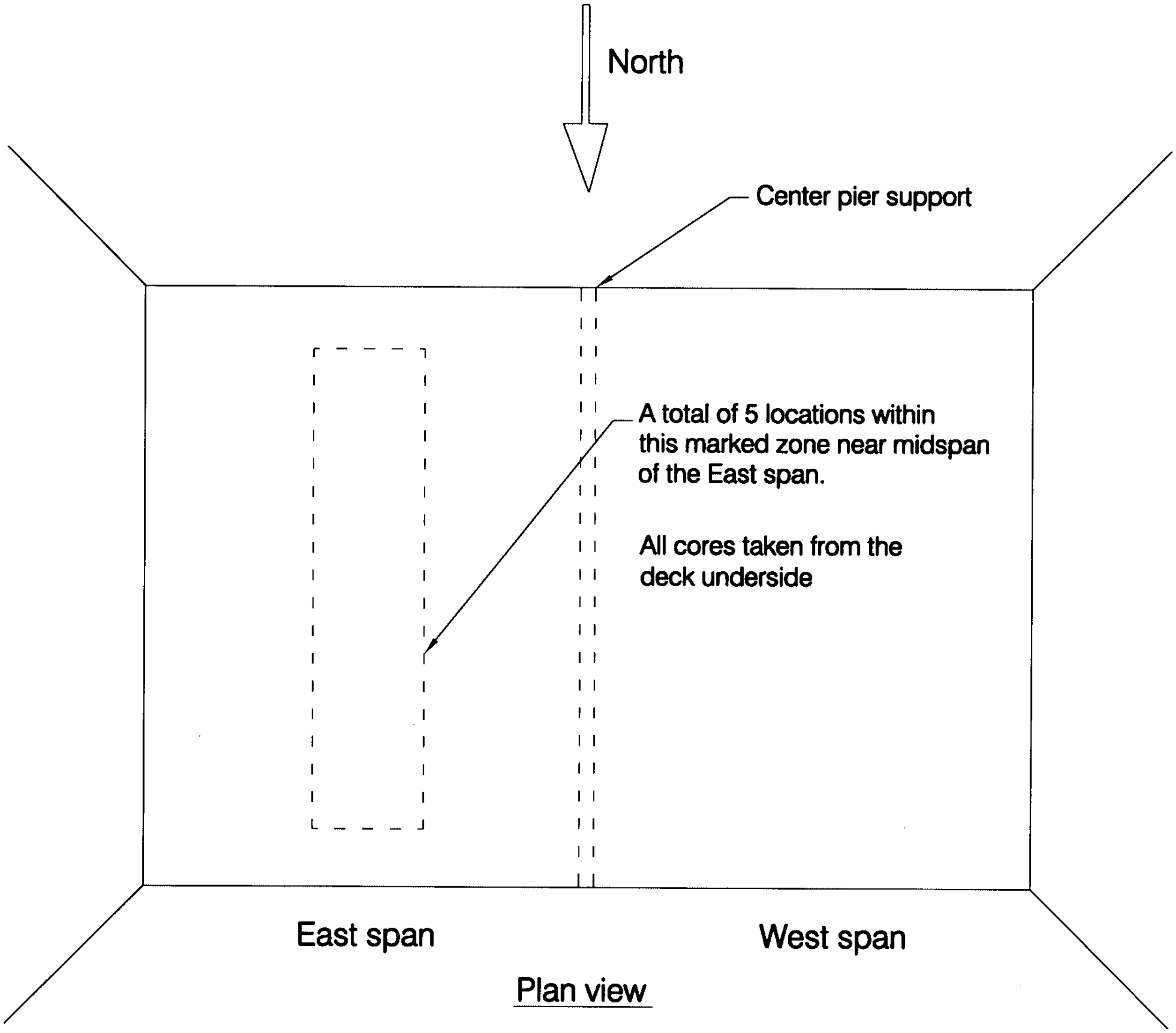

Figure 16—Core sample locations for the Old Vanderbilt bridge (Otsego County).