FY2013 RESEARCH PROJECT PROPOSAL

Organization:	**University of Minnesota Duluth**
Project Title:	**Development and Integration of Advanced Timber Bridge Inspection Techniques for NBIS**
Need Statement Number:	**211**
Total Project Budget:	**$199,786**
Total Project Duration:	**July 1, 2012 - June 30, 2014**
MnDOT or Local Champion:	**John Welle, Sue Miller, David Conkel, Matt Hemmila**

Proposal Type: (check all that apply)
For a description of proposal types, visit ***https://www.cts.umn.edu/Research/ForResearchers/RFP/2013***.

- ☒ MnDOT or LRRB Research Need: Research Need Statement # (if applicable) _211_____
- ☐ LRRB Knowledge-Building Priority: KB # _____
- ☐ Transitway Impacts Research Program Research Priority
- ☐ Other Transportation Research Need (Unsolicited Proposal)

1. Project Team:

- **Principal Investigator:**
  Name: Brian K. Brashaw (resume included)
  Position Title: Program Director, UM Duluth, Natural Resources Research Institute
  Phone: 218-720-4248; E-Mail: bbrashaw@nrri.umn.edu
- **Subcontractor:**
  Name: Brent Phares, P.E., Ph.D. (resume included)
  Organization: Iowa State University
  Project Role: Bridge engineer
- **Subcontractor:**
  Name: James Wacker, P.E. (resume included)
  Organization: USDA Forest Service, Forest Products Laboratory, Madison, WI
  Project Role: Bridge inspector, engineer and outreach
- **Subcontractor:**
  Name: Todd Lang. P.E. and Nick Sovell, P.E. (resume included)
  Organization: HDR Engineering, Inc., Minneapolis, MN
  Project Role: Bridge inspection and engineering assessments

2. Proposal Summary and Objective(s):

Minnesota's Nobles County experienced a timber bridge failure in 2010, raising concerns among city, county and state engineers about the current practice of timber bridge inspections. Inspections for timber bridges have been mostly limited to visual inspection, hammer sounding and probing. These techniques have proven appropriate for advanced decay detection, but are inadequate for early stage or internal deterioration. It is critical that efforts be conducted to develop and implement advanced timber inspection techniques into routine bridge inspections in accordance with National Bridge Inspection Standards (NBIS) requirements. This project will result in improved assessment information that can be used to improve the safety and reliability of Minnesota's bridges. An experienced research team will identify and help implement an inspection protocol for Minnesota's timber bridges (with an emphasis on timber substructure) that can accurately assess structural condition and support the load rating process. Key milestones include the development of standard inspection protocols, integration of the results into bridge data management software, development of a customized inspection manual, outreach training for MnDOT districts, recommendation of equipment purchases, and completion of an economic assessment on the use of advanced inspection techniques.

3. Literature Search and Summary of Relevant Previous Work:

During the past seven years, the project applicant (University of Minnesota Duluth Natural Resources Research Institute (UMD NRRI)) and their research cooperators have worked with several Minnesota counties to conduct inspections of timber bridges, to develop new approaches for inspecting these bridges and to provide presentations on the potential of new inspection technology. It was clearly noted through this interaction that current assessments of timber transportation structures by state, county and city inspectors in Minnesota are limited to visual inspection and physical procedures (hammer, picks, and probes). A study on the reliability of visual inspections conducted on highway bridges (Phares et al. 2001) revealed condition ratings based solely on visual assessments to be highly variable and to yield inaccurate results. In response, a large research initiative was initiated at the US Department of Transportation, Federal Highway Administration (FHWA) to broaden the use of nondestructive evaluation (NDE) techniques to help improve the state of the practice for highway bridge inspections (Washer 2000). In response, the FHWA's Bridge Inspector's Reference Manual (2002, revised 2006) provides information on the inspection of timber bridges to include visual, physical (hammer, pick, boring, moisture content) procedures, along with advanced NDE techniques such as Pol-Tek, spectral analysis, ultrasonic, shigometer and vibration. However, there is no reference to currently accepted best practices inspection technologies for wood bridges that include stress wave timing and resistance microdrilling.

Following the catastrophic bridge failure in Minnesota, the American Society of Civil Engineers Structural Engineering Institute (ASCE SEI) and FHWA cosponsored a Bridge Workshop – Enhancing Bridge Performance (ASCE SEI 2008). Several key outcomes regarding timber bridges included:

- *"A major factor which is leading to poor bridge performance and reduced service lives of timber structures was seen as being lack of sufficient education and knowledge by engineers about timber bridges (extending across the design-fabrication-construction-inspection-load ratings spectrum), because timber is the least familiar bridge material.*
- *The critical deficiency in the type of data that is currently collected in standard bridge inspection/ management practices includes the subjective nature of the inspection data. Too much reliance is given on visual inspection. It was a general feeling that the information that is currently gathered is not adequate to judge the performance of bridges. Although visual inspection will never be replaced and does not need to be, it can be supplemented with quantitative inspection data, and better forecasting methodologies. NDE technologies can supplement visual inspection."*

The UMD NRRI and their cooperators have worked to develop and transfer the use of advanced techniques like stress wave timing, moisture meters, and resistance drilling to inspectors and engineers to significantly improve the reliability of condition assessment and evaluations of timber structures through several MnDOT/LRRB, FHWA and UMD projects (Brashaw 2011, Brashaw 2009, Brashaw et al 2005 (2), and Ross et al 2004). The team has worked cooperatively with several Minnesota counties (St. Louis, Aitkin, and Otter Tail) and has also conducted inspections as requested by MnDOT bridge office. They have also worked to develop and assess vibration testing of timber bridges as a means to monitor structural health (Brashaw 2009).

4. Expected Benefits, Users, and Implementation Opportunities:

Wood is a natural occurring engineering material that is prone to deterioration caused by decay fungi and insect attack. The application of preservative treatment greatly enhances the durability of timber bridge components, but regular inspections are vital for the implementation of timely repairs and proactive maintenance programs. As noted in the USFS Timber Bridge Manual (Ritter 1990), "Bridge members infected with decay fungi experience progressive strength loss as the fungi develop and degrade the wood structure. The degree of strength reduction depends on the area of the infection and the stage of decay development, whether advanced, intermediate, or incipient." Background discussions with Mn/DOT bridge inspection program managers and other Minnesota County engineers reveal that current timber inspection procedures in Minnesota are limited to visual inspection of the wood components, sounding with a hammer and coring to confirm suspected damage areas. These techniques have proved adequate for advanced decay detection, but are inadequate when the damage is early stage, located internally in

members, and near or below the water line. Further, the current bridge inspection software limits the inputs that can be entered for timber more so than any other material. In some cases these limits overestimate the bridge sufficiency rating, potentially giving the engineer a false sense of security.

In this project, the research team will identify advanced timber bridge inspection equipment, develop inspection protocols (with an emphasis on substructure), identify approaches to implement the inspections into bridge data management software, and transfer this information to inspectors and engineers in Minnesota. This project will provide clear implementation strategies that can be used to accurately identify deteriorated structural timber members and provide key information that can be used to adjust load ratings, develop repair strategies and improve maintenance. One outcome from the project will be a recommendation for the purchase of timber inspection equipment for sharing within the State. Training and outreach will be conducted for inspectors and engineers for each District. By providing training and access to advanced timber inspection equipment, the project will improve the safety and reliability of Minnesota's timber bridges. Key information will be available to repair bridges, extending their service life. The results of the project will be assessed through successful development of inspection results into bridge inspection software programs, completion of training for inspectors and engineers, and use of the equipment.

5. Summary of Research Methodology: This project will help Minnesota bridge inspectors and engineers develop and implement advanced inspection techniques for timber bridges and serve as a model for State DOTs and their partners. Various nondestructive tools and methods for conducting state-of-the-art inspections are to be highlighted in a guidance manual and are to be demonstrated in training seminars. These efforts should help to identify those structures needing repair or replacement and to safely extend the service lives of Minnesota's timber bridges.

6. Tasks Descriptions, Durations, and Budgets:

Task 1: Identification of inspection technologies for timber bridges.
Description: A worldwide review of commercial nondestructive inspection technologies for timber bridges will be completed and used to generate a list of equipment that could be used in Minnesota. Information on equipment costs and recommended application will be collected. Demonstrations or access to equipment will be requested from the manufacturer should the project team not currently own the equipment. Promising new technologies will be carefully evaluated by conducting a carefully designed and controlled research study. Information collected in Task 1 will be summarized for review by the technical advisory panel (TAP) to create a prioritized list for use in Task 2.

Anticipated Start Date: July 1, 2012 **Anticipated End Date**: September 30, 2012
Duration: 3 months **Budget:** $9,989
Deliverable: Prioritized list of inspection equipment for development of inspection protocols.

Task 2: Development of timber bridge inspection protocols.
Description: Timber bridge inspection protocols for the most promising equipment will be developed. These protocols will be developed for all timber members including piling, pile caps, girders, decks, abutments and wing walls, and other members. A special emphasis will be on techniques near or below the water line. The focus of the effort will be to create user-friendly, easily understood and time-efficient inspection protocols specific to timber bridge components. The project team will engage inspectors from counties that have high numbers of timber containing bridges to accurately reflect current protocols.

Anticipated Start Date: October 1, 2012 **Anticipated End Date**: March 31, 2013
Duration: 6 months **Budget:** $39,957
Deliverable: Inspection protocols for timber bridges that can be used by inspectors and engineers.

Task 3: Develop condition reporting forms that supplement NBIS formats.
Description: Condition reporting formats will be developed concurrently with the development of inspection procedures (Task 2). These formats will be generated for use with the current software or to supplement the software used by Minnesota inspectors and engineers. MnDOT has implemented a new

Structure Information Management System (SIMS), which replaced the Pontis online application. Use of SIMS is required for entering, submitting, and managing all bridge inspection information. The project team will interface with state staff to develop appropriate reporting formats and forms for use by inspectors to include element level assessments. The project team will use proven continuous improvement approaches (A3 planning and Plan-Do-Check-Adjust) to ensure acceptability.

Anticipated Start Date: October 1, 2012 **Anticipated End Date**: March 31, 2013
Duration: 6 months **Budget:** $39,957
Deliverable: Condition reporting formats that provide key information to supplement NBIS procedures.

Task 4: Develop an inspection manual for timber bridges.
Description: Utilizing the results from Tasks 2 and 3, a customized timber bridge inspection field manual will be developed. This manual will provide information and understanding of deterioration mechanisms, inspection equipment, inspection protocols, condition reporting formats and the process for integrating the inspection results into NBIS formats and bridge data management software. This manual will provide technical guidance for each inspection tool, including data sampling, data collection, and data quality assurance. The final chapter will provide a detailed case study of a timber bridge inspection. The focus of the effort will be to create user-friendly, easily understood and time-efficient inspection information that can be used during the training sessions (Task 7). This information will also be placed on the MnDOT bridge portal and include web-based videos.

Anticipated Start Date: April 1, 2013 **Anticipated End Date**: August 31, 2013
Duration: 5 months **Budget:** $29,968
Deliverable: Timber bridge inspection manual customized for Minnesota.

Task 5: Complete an economic assessment of the proposed inspection protocol for timber bridges.
Description: The project team will focus on developing inspection procedures that can be implemented into the current NBIS process. An emphasis of this research will be to develop cost-effective strategies that can be supported by state, county and other engineers. To validate, a preliminary cost projection will be developed in cooperation with several volunteer counties. An estimate of the inspection time will be developed. Interviews will be held with several county engineers/inspection supervisors to develop information on the benefits to reduce the probability of a catastrophic bridge failure ensuring safety of motorists, to understand extended service life, reduced load ratings, or other economic criteria.

Anticipated Start Date: June 1, 2013 **Anticipated End Date**: August 31, 2013
Duration: 3 months **Budget:** $19,979
Deliverable: Economic assessment of the inspection protocol used for timber bridges.

Task 6: Recommend a set of inspection tools/equipment for NDE evaluations of timber bridges.
Description: Based on the assessment of the potential inspection equipment by the TAP and other interested parties, a set of inspection equipment for timber bridges will be recommended for purchase by MnDOT or for other entities. Upon purchase, this equipment will be located at some central location and be available to counties, cities or MnDOT Districts. It will be preassembled into ruggedized shipping containers for protection and rapid deployment to MN public agencies. The project team will be available during the project to provide technical assistance and hands-on support as appropriate.

Anticipated Start Date: August 1, 2013 **Anticipated End Date**: September 30, 2013
Duration: 2 months **Budget:** $9,989
Deliverable: Equipment specifications for recommended purchase by MnDOT or other agencies.

Task 7: Conduct inspection training (one-day: classroom and hands-on) for each MnDOT District.
Description: In cooperation with the MnDOT Bridge Office, one-day workshops will be conducted in 6-8 locations throughout the state. This training will be based on the Timber Bridge Inspection Field Manual developed in Task 4. The sessions will be conducted for city, county and state bridge staff and include classroom and field-testing of an appropriate timber bridge. In the field component, inspectors

will receive hands-on practical experience with inspection procedures and equipment. They will be distributed into small groups and rotated through stations to develop experience with recommended equipment. Prior to the training, the project team will select a suitable field bridge, conduct a preliminary inspection to identify areas of concern and plan for a safe field inspection.

Anticipated Start Date: September 1, 2013 **Anticipated End Date**: December 31, 2013
Duration: 4 months **Budget:** $29,968
Deliverable: Timber bridge inspection training for all interested Minnesota agencies.

Task 8: Draft Final Report
Description: A draft final report will be prepared, following MnDOT publication guidelines, to document project activities, findings and recommendations. This report will be submitted through the publication process for technical and editorial review.

Anticipated Start Date: January 1, 2014 **Anticipated End Date**: February 28, 2014
Duration: 2 months **Budget:** $9,989
Deliverables: Draft final report.

Task 9: Final Report Completion.
Description: During this task, technical and editorial comments from the review process are incorporated into the document as appropriate. Reviewers will be consulted for clarification or discussion of comments. A revised final report will be prepared and submitted for publication.

Anticipated Start Date: March 1, 2014 **Anticipated End Date**: June 30, 2014
Duration: 4 months **Budget:** $9,989
Deliverables: Final report.

7. Overview of Project Schedule and Budget:

Months	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21-24	Budget
Task 1	x	x	x																			$9,989
Task 2				x	x	x	x	x	x													$39,957
Task 3				x	x	x	x	x	x													$39,957
Task 4										x	x	x	x	x								$29,968
Task 5												x	x	x								$19,979
Task 6														x	x							$9,989
Task 7															x	x	x	x				$29,968
Task 8																			x	x		$9,989
Task 9																					x	$9,989

8. Fiscal Year Funding Split:

Fiscal Year	Timeframe	Budget	Comments
FY13	July 1, 2012 – June 30, 2013	$89,903	
FY14	July 1, 2013 – June 30, 2014	$109,882	
TOTAL		$199,786	

9. Budget Details:

Salaries/Benefits	Description	Costs
	Professional/Academic Staff:	**$52,961**
	Undergraduate Students:	**$10,002**
	Other (Civil Service, scientists, etc.)	**$37,326**
Non-Salary	Equipment:	**n/a**
	Supplies:	**$1,015**

	Travel:	**$5,856**
	Other: Printing field manuals	**$3,045**
Subconsultants	Iowa State, USDA FPL, HDR Engineering	**$89,581**
Indirect Costs	(Iowa State only - included in subconsultants)	-
TOTAL		**$199,786**

10. Budget Justification/Specialized Equipment: No specialized equipment will be purchased using grant funds, although a recommendation will be made to purchase timber inspection equipment.

11. Matching Funds, In-Kind or other Contributions: In-kind funds will be provided by USDA FPL in the form of salary and fringe ($10,000). Although a formal commitment could not be made before proposal submission, the research team and the Iowa Highway Research Board have had discussions about expanding the project into a pooled fund project. The Board has agreed to meet and vote on initiating participation and at what financial level.

12. Intellectual Property/Trade Secret Information: None.

13. Agency Assistance (MnDOT or other): Assistance from the MnDOT bridge engineering group and various county engineers/inspectors will be desired to support the project activities. A one-day workshop is planned that will require participation from public agencies at the state, county and city levels.

14. Resumes for PI and co-investigator(s):

☒ Resumes are attached as PDF file (Brashaw, Phares, Wacker, Sovell)

15. References:

Brashaw, B.K. 2011. Inspection and Condition Assessment of Timber Bridges. Presentation during MnDOT Annual Bridge Training. Cloquet, Rochester, St. Paul and Detroit Lakes, Minnesota.

Brashaw, B.K., R. J. Vatalaro, J. P. Wacker and R.J. Ross. 2005. Condition Assessment of Timber Bridges: 1. Evaluation of a Micro-Drilling Resistance Tool. Gen. Tech. Report. FPL-GTR-159. U.S. Department of Agriculture, Forest Service, Forest Products Laboratory.

Brashaw, B.K.; Vatalaro, R.; Wacker, J.P.; Ross, R.J. 2005. Condition Assessment of Timber Bridges: 2. Evaluation of Several Stress-Wave Timer Devices. Gen. Tech. Report FPL–GTR–160. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 12 p.

Brashaw, B.K, R. Vatalaro, X. Wang, K. Sarvela, M. Verreaux and J.P. Wacker. 2009. Development of flexural vibration inspection techniques to rapidly assess the structural health of rural bridge systems - Phase II. CTS 09-40, Intelligent Transportation Systems (ITS) Institute, Center for Transportation Studies, University of Minnesota.

Phares. B.M.; Rolander, D.D.; Graybeal, B.A.; Washer, G.A. 2001. Reliability of visual bridge inspection. Public Roads, Vol. 64, No. 5. Washington, DC: Federal Highway Administration.

Ritter, Michael A. 1990. *Timber Bridges-Design, Construction, Inspection, and Maintenance*, EM7700-8. Washington, DC: USDA Forest Service. 944p.

(Book) Ross, R.J., B.K. Brashaw, X. Wang, R. White, and R.F. Pellerin. 2004. *Wood and Timber Condition Assessment Manual.* Forest Products Society, Madison, WI.

U.S. Department of Transportation, Federal Highway Administration. October 2002 (Revised December 2006). *Bridge Inspector's Reference Manual. Volume 1*. Publication No. FHWA NHI 03-001.

Wang, X.; Wacker, J.P.; Morison, G.; Ross, R.J.; Brashaw, B.K.; Vatalaro, R.; Erickson, J. 2005. Nondestructive Evaluation of Single Span Timber Bridges using a Vibration Method. Res. Pap. FPL–RP–627. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory.

Washer, G.A. 2000. Developing NDE technologies for infrastructure management. Public Roads, Vol. 63, No. 4. Washington, DC: Federal Highway Administration.