INSTRUCTIONS:
Project Managers and/or research project investigators should complete a progress report at least every three months during the project duration. Reports are due the 5th of the month following the end of the quarter. Please provide a project update even if no work was done during this reporting period.

<table>
<thead>
<tr>
<th>Project #</th>
<th>Report Period</th>
<th>Year: 2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>26962G</td>
<td>□ Q1 (Jan-Mar)</td>
<td>X Q2 (Apr-Jun) □ Q3 (Jul-Sep) □ Q4 (Oct-Dec)</td>
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</tbody>
</table>

Project Title:
The Living Bridge: A Benchmark for Bridge Monitoring
The Living Bridge: Tidal Turbine Deployment System

Project Investigator: Erin S. Bell  
Project Co-Investigators: Martin Wosnik, Kenneth Baldwin
Phone: (603)862-3850  
E-mail: erin.bell@unh.edu

Research Start Date:  
Sample  
July 1, 2016

Research End Date:  
September 30, 2018

Project schedule status:  
□ On schedule  
□ Ahead of schedule X Behind schedule

Brief Project Description:
This project is a collaborative project between the civil and environmental engineering, mechanical and ocean engineering programs at UNH, the NHDOT and several industrial partners to install an array of structural health monitoring, environmental and estuarine sensors on the Memorial Bridge in Portsmouth, New Hampshire that will be powered by a tidal turbine attached to one of the bridge piers. The funding for the Tidal Turbine Deployment System is leveraged with funding provided by the National Science Foundation’s Partnerships for Innovation (PFI) Program, The Living Bridge: The Future of Smart, Sustainable User-Centered Transportation Infrastructure.

Progress this Quarter (include meetings, installations, equipment purchases, significant progress, etc.):

Benchmark for Bridge Monitoring:
The final instrumentation plan for the structural health monitoring was discussed at the June 29th 2016 technical advisory group meeting in Concord, NH, and was approved on July 18 2016. The structural sensors were installed on the bridge structure in March 2017. The installation was complete on March 8 2017. The sensors are operational and reading data - at present to the BDI office. The integration with the local server and database is being finalized with Northeast Integration and is currently being completed (June/July 2017). The integration of sensors data is still underway and local control of the sensors is anticipated to be established by July 7th 2017.

The structural model of the Memorial Bridge in SAP2000® is complete. This model is for the Portsmouth span and lift tower only. Graduate student, Timothy Nash, conducted a study of wind loads developed from AASHTO, ACSE7-10 and European codes to predict the structural response of the lift tower. Tim defended his thesis and graduated with his masters degree in December 2016. A journal paper on this work will be submitted in July 2017. This information will be compared to the measured structural response of the tower, once the data integration is completed.

A detailed model of the gusset-less truss connection in ABAQUS® is completed. The response from this model is the basis for a quantitative set of stiffness values (stiffness matrix) to represent the connection in the structural SAP® model.

A set of multiscale models of the bridge and connection is under development at UNH in Lusas®. This program was chosen to mirror the modeling done during bridge design by HNTB. A comparison with the SAP® model is underway to refine the Lusas® models in preparation for calibration with collected field data from the load test that will be conducted in July 2017. The load test was originally schedule for June 2017 but the delay in data integration has delayed the test. On June 15, 2017, PI Bell met with G. Popien at the bridge and discussed that G. Popien would prefer that local sensor control was established prior to the load test and that a “mock” load test to test the data acquisition protocols was recommended prior to the load test, as well.
The strain gauges on the vertical guide posts will be installed once the conduit installation of the tidal turbine connection is completed. This installation will be completed by Bridge Diagnostics, INC and coordinated with the NHDOT for July 2017.

PI Bell continues to communicate with bridge designer, Ted Zoli, both in live and virtual meetings. The last conference call as held on April 14th 2017 and the newest live meeting in New York is planned for Summer 2017.

**Tidal Turbine Deployment System**

The tidal turbine deployment system consists of vertical guide posts (VGPs) and a turbine deployment platform (TDP) on which the tidal turbine will be installed.

The VGP installation by Pepperell Cove Marine was completed by 13 December 2016. The TDP was first test-deployed at the bridge for one tidal cycle on 31 March 2017 (spring flood tide). The TDP was then moved to the UNH Research Pier in Newcastle, NH, where it was outfitted with estuarine instrumentation. Also, during the test deployment it was discovered that the pile guides were not functioning as designed and expected (were not riding as smoothly up and down the VGPs as expected). The pile guides were redesigned and fabricated, and installed on the TDP.

The TDP was re-deployed with instruments and new pile guides at Memorial Bridge on 22 June 2017. The TDP was deployed by our marine contractors Pepperell Cove Marine. We have been carefully monitoring how the TDP performs in currents, waves and wind – so far the system has been performing as designed and expected. Initially we checked on the TDP performance in person every tidal cycle, then daily, and have now just reduced it to twice weekly.

UNH held a meeting with representatives from the US Coast Guard and the NH Marine Patrol to discuss the operation, monitoring and removal of the tidal turbine deployment system on 31 May 2017 (NHDOT, NH Port Authority, Army Corps of Engineers were invited, but did not attend). An emergency management protocol was established and reviewed, and an emergency contact list was distributed to all agencies and stakeholders.

The instruments are currently connected through a temporary connection to the bridge; a permeant solution with conduit installed by NEI is currently being worked in. The power and communication connections from the TDP to the Memorial Bridge are under discussion and design. The energy coming from the tidal turbine will be grid-tied via an inverter and net-metered, using a separate enclosure and separate disconnect. The net-metering approach would the simplest and most efficient/effective from an electrical connection point of view. Our turbine partners, Instream Energy Systems, have experience with these types of grid-tie inverter systems, the hardware they propose to use (Siemens SINAMICS S120 drive system) is UL 1741 certified. Our local integration partner for instrumentation, data systems and power, Northeast Integration of Portsmouth, NH, is intimately familiar with power supply and cabling on Memorial Bridge, and will design and implement the turbine electrical connection. UNH and NEI have discussed net-metering with the distributed generation manager at Eversource, the local utility.

We propose the following, in general terms: Install an inverter (electrical drive) in a separate enclosure, with a separate disconnect. This will now likely be installed on the TDP, as opposed to the pier cap of Pier #2. The electric output from the tidal turbine will be net-metered over the period of one year. After the project concludes and is being decommissioned, all can be taken away at once. We are working to minimize any disruption to the bridge grid that the installation and decommissioning will cause.

**The Living Bridge**

Graduate student Ian Gagnon presented on the Living Bridge Project at the UNH Graduate Research Conference on 12 April 2017.

Three different (undergraduate) senior project teams from the Departments of Mechanical Engineering, Civil and Environmental Engineering and Computer Science presented at the UNH Undergraduate Research Conference (largest of its kind in the United States) on 19 April 2017 in the Whittemore Center at the University of New Hampshire.

Graduate student Ian Gagnon gave a poster presentation on the Living Bridge Project at the School of Marine Science and Ocean Engineering Graduate Student Research Symposium on 27 April 2017.

Co-PI Wosnik presented on the Living Bridge Project at the Marine Energy Technology Symposium, held as part of National Hydropower Association’s National Hydropower Week in Washington DC in May 2017:

NHDOT SPR2 Quarterly Reporting
Items needed from NHDOT (i.e., Concurrence, Sub-contract, Assignments, Samples, Testing, etc):

UNH will need access protocols for the data closet at the bridge for maintenance of the data acquisition system.

UNH will require access to the pier cap for strain gauge installation on the VGP by Bridge Diagnostics, INC, once the conduit installation by Northeast Integration is complete.

UNH will require the NHDOT support for the load test.

UNH will need the NHDOT to decide on the future of the memorialbridgeproject.com website. Currently, the site is hosted at UNH and the domain name will expire in December 2017.

Anticipated research next 3 months:

Benchmark for Bridge Monitoring:
The integration of the structural health and environmental instrumentation the sensors for remote access is scheduled for completion in July 2017.

The validation of the structural models of the Memorial Bridge in Lusas® as well as local model of selected gusset-less connections at the Memorial Bridge with respect to collected data in Summer 2017. Calibration of the structural models for condition and performance assessment with respect to design verification.

Tidal Turbine Deployment System

The deployment of tidal turbine deployment platform (TDP) with estuarine sensors at the Memorial Bridge occurred in June 2017. The installation of the tidal turbine on the deployment platform is planned for fall of 2017, with power and communication connection to be installed in July/August 2017 by NEI.
Circumstances affecting project: Describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope, and budget, along with recommended solutions to those problems.

As described in the “Progress this Quarter” section of this report, the schedule delay and increased cost related to the electrical conduit negatively impact this project.

<table>
<thead>
<tr>
<th>Tasks (from Work Plan)</th>
<th>Planned % Complete</th>
<th>Actual % Complete</th>
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<tbody>
<tr>
<td><strong>Living Bridge: Creating a Benchmark for Bridge Monitoring</strong></td>
<td></td>
<td></td>
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<tr>
<td>Project Coordination</td>
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<td>100</td>
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<tr>
<td>Structural Model Creation</td>
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<td>Design the instrumentation Plan</td>
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<tr>
<td>Sensor Deployment</td>
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<tr>
<td>Data Collection and Model Calibration</td>
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<tr>
<td>Incorporation of collected data and model into NHDOT protocols</td>
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<tr>
<td>Final Report and Adoption Recommendation</td>
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<tr>
<td><strong>Tidal Turbine Deployment Structure</strong></td>
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<td>Deployment Structure Design</td>
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<tr>
<td>Project Permitting</td>
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<tr>
<td>Installation of Support Posts</td>
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<tr>
<td>Procurement of the Turbine deployment barge</td>
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<tr>
<td>Site Installation</td>
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<tr>
<td>Electrical Connection</td>
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<td>Final Report and Poster</td>
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