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Victoria F. Sheehan
Commissioner

THE STATE OF NEW HAMPSHIRE
DEPARTMENT OF TRANSPORTATION



William Cass, P.E.
Assistant Commissioner

His Excellency, Governor Christopher T. Sununu
and the Honorable Council
State House
Concord, New Hampshire 03301

Bureau of Materials & Research
March 5, 2019

REQUESTED ACTION

1. Authorize the Department of Transportation to enter into a **SOLE SOURCE** Cooperative Project Agreement with the University of New Hampshire Sponsored Programs Administration (vendor 177867), Durham, New Hampshire, for a fee not to exceed \$111,812.00 for a cooperative evaluation of an alternate method of estimating soil infiltration rates used to assess the suitability of a site for various stormwater best management practices, effective upon Governor and Council approval through June 30, 2021. 100% Federal Funds.
2. Authorize the Department of Transportation to enter into a **SOLE SOURCE** Cooperative Project Agreement with the University of New Hampshire Sponsored Programs Administration (vendor 177867), Durham, New Hampshire, for a fee not to exceed \$100,249.00 for a cooperative evaluation of a smart rock sensor system that can provide the necessary field response data to improve rockfall simulation software models, effective upon Governor and Council approval through June 30, 2021. 100% Federal Funds.

Funding is available as follows for FY 2019 and is contingent upon the availability and continued appropriation of funds in FY 2020 and FY 2021, with the ability to adjust encumbrances through the Budget Office between State Fiscal Years if needed and justified:

	<u>FY 2019</u>	<u>FY 2020</u>	<u>FY 2021</u>
04-96-96-962015-3036 SPR Research Funds			
046-500464 General Consultants Non-Benefit	\$148,444.00	\$31,809.00	\$31,808.00

EXPLANATION

The following two (2) research studies will each address an immediate Department need, are unique to New Hampshire's environment and conditions, thereby requiring substantial local experience and are directly aligned with a particular area of University expertise. In addition, the Principal Investigator is a nationally recognized expert in his respective field. As such, the proposed work does not lend itself to a selection process that includes private industry or out-of-state organizations and it is in the Department's and the State's best interest to work directly with the University of New Hampshire.

This work is part of the Department's Statewide Planning and Research (SPR) program. The Department of Transportation and the University of New Hampshire (UNH) is a long-standing cooperative relationship of transportation research. This relationship has been mutually beneficial, culminating in savings to the State while enhancing work force development and maintaining New

Hampshire's position on the leading edge of new technology. Research studies conducted by UNH for the Department have led to numerous innovations in the highway and bridge industry, including such improved pavement design, increased use of recycled materials, stormwater management evaluation, and rapid construction techniques.

Statewide-SPR 26962U, Improved Practices for Determining the Infiltration Characteristics of Soils for Design of Stormwater BMPs

The Department is collaborating with the University of New Hampshire (UNH) to conduct a cooperative research study, "Improved Practices for Determining the Infiltration Characteristics of Soils for Design of Stormwater BMPs", to evaluate an alternate method of estimating soil infiltration rates, used to assess the suitability of a site for various stormwater best management practices (BMPS). The current practice is a variation of the borehole infiltration test prescribed in the NHDES Alteration of Terrain (AoT) rules, a labor intensive and time consuming process. The alternate method is a permeafor device, an in-situ hydraulic profiling tool that provides a quick estimate of the permeability profile of soil layers. This project will compare the results of this alternative to the existing test method and will provide a workable permeafor device suitable for implementation on NHDOT projects. Cost savings are anticipated due to the reduced labor and time associated with the permeafor method for a total fee not to exceed \$111,812.00 effective upon Governor and Council approval though June 30, 2021.

Statewide-SPR 26962Z, Use of Smart Rocks to Improve Rock Slope Design

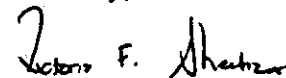
The Department is collaborating with the University of New Hampshire (UNH) to conduct a cooperative research study, "Use of Smart Rocks to Improve Rock Slope Design", to evaluate a smart rock sensor system that, when imbedded in a natural rock, can provide the necessary field response data to calibrate and revise existing rockfall simulation software models. This proposed research project will conduct rockfall experiments with a smart rock on 10 rock cuts that are rated A or B according to the current practice, New Hampshire Rockfall Hazard Rating System (RHRS). This project is expected to refine hazard ratings of rock slopes to increase safety against rockfall, construct better engineered slopes, and reduce short and long-term maintenance costs for a total fee not to exceed \$100,249.00 effective upon Governor and Council approval though June 30, 2021.

These two (2) Agreements have been approved by the Attorney General as to form and execution. Copies of the fully-executed Agreements are on file at the Secretary of State's Office and the Department of Administrative Services, and subsequent to Governor and Council approval will be on file at the Department of Transportation.

This project funding is 80% Federal Funds with 20% state match. Turnpike toll credit is being utilized for match requirements, effectively using 100% Federal Funds.

It is respectfully requested that authority be given to enter into these sole-source Agreements for consulting services as outlined above.

Sincerely,



Victoria F. Sheehan
Commissioner

COOPERATIVE PROJECT AGREEMENT

between the

STATE OF NEW HAMPSHIRE, Department of Transportation

and the

University of New Hampshire of the UNIVERSITY SYSTEM OF NEW HAMPSHIRE

- A. This Cooperative Project Agreement (hereinafter "Project Agreement") is entered into by the State of New Hampshire, **Department of Transportation**, (hereinafter "State"), and the University System of New Hampshire, acting through **University of New Hampshire**, (hereinafter "Campus"), for the purpose of undertaking a project of mutual interest. This Cooperative Project shall be carried out under the terms and conditions of the Master Agreement for Cooperative Projects between the State of New Hampshire and the University System of New Hampshire dated November 13, 2002, except as may be modified herein.
- B. This Project Agreement and all obligations of the parties hereunder shall become effective on the date the Governor and Executive Council of the State of New Hampshire approve this Project Agreement ("Effective date") and shall end on **06/30/21**. If the provision of services by Campus precedes the Effective date, all services performed by Campus shall be performed at the sole risk of Campus and in the event that this Project Agreement does not become effective, State shall be under no obligation to pay Campus for costs incurred or services performed; however, if this Project Agreement becomes effective, all costs incurred prior to the Effective date that would otherwise be allowable shall be paid under the terms of this Project Agreement.
- C. The work to be performed under the terms of this Project Agreement is described in the proposal identified below and attached to this document as Exhibit A, the content of which is incorporated herein as a part of this Project Agreement.

Project Title: Improved Practices for Determining the Infiltration Characteristics of Soils for Design of Stormwater BMPs (SPR Project # 26962U)

- D. The Following Individuals are designated as Project Administrators. These Project Administrators shall be responsible for the business aspects of this Project Agreement and all invoices, payments, project amendments and related correspondence shall be directed to the individuals so designated.

State Project Administrator

Name: Ann Scholz
 Address: NHDOT Bureau of Materials & Research
5 Hazen Dr. PO Box 483
Concord, NH 03302-0483
 Phone: 603-271-1659

Campus Project Administrator

Name: Karen Rooney
 Address: University of New Hampshire
Sponsored Programs Administration
51 College Rd. Rm 116
Durham, NH 03824
 Phone: 603-862-5412

- E. The Following Individuals are designated as Project Directors. These Project Directors shall be responsible for the technical leadership and conduct of the project. All progress reports, completion reports and related correspondence shall be directed to the individuals so designated.

State Project Director

Name: Aaron Smart
 Address: NHDOT Bureau of Materials & Research
7 Hazen Drive, PO Box 483
Concord, NH 03302-0483
 Phone: 603-271-1655

Campus Project Director

Name: Dr. Jean Benoit
 Address: University of New Hampshire
Kingsbury Hall, W183
33 Academic Way
Durham, NH 03824
 Phone: 603-862-1419

F. Total State funds in the amount of \$111,812 have been allotted and are available for payment of allowable costs incurred under this Project Agreement. State will not reimburse Campus for costs exceeding the amount specified in this paragraph.

Check if applicable

Campus will cost-share _____ % of total costs during the term of this Project Agreement.

Federal funds paid to Campus under this Project Agreement are from Grant/Contract/Cooperative Agreement No. N/A from **USDOT Federal Highway Administration** under CFDA# **20.205**. Federal regulations required to be passed through to Campus as part of this Project Agreement, and in accordance with the Master Agreement for Cooperative Projects between the State of New Hampshire and the University System of New Hampshire dated November 13, 2002, are attached to this document as Exhibit B, the content of which is incorporated herein as a part of this Project Agreement.

G. Check if applicable

Article(s) _____ of the Master Agreement for Cooperative Projects between the State of New Hampshire and the University System of New Hampshire dated November 13, 2002 is/are hereby amended to read:

H. State has chosen **not to take** possession of equipment purchased under this Project Agreement.
 State has chosen **to take** possession of equipment purchased under this Project Agreement and will issue instructions for the disposition of such equipment within 90 days of the Project Agreement's end-date. Any expenses incurred by Campus in carrying out State's requested disposition will be fully reimbursed by State.

This Project Agreement and the Master Agreement constitute the entire agreement between State and Campus regarding this Cooperative Project, and supersede and replace any previously existing arrangements, oral or written; all changes herein must be made by written amendment and executed for the parties by their authorized officials.

IN WITNESS WHEREOF, the University System of New Hampshire, acting through the **University of New Hampshire** and the State of New Hampshire, _____ have executed this Project Agreement.

By An Authorized Official of:

University of New Hampshire

Name: Karen M. Jensen

Title: Manager, Sponsored Programs Administration

Signature and Date:  2/28/19

By An Authorized Official of: the New Hampshire Office of the Attorney General

Name: Emily C. Goering

Title: Assistant Attorney General

Signature and Date: Emily C. Goering 4/1/19

By An Authorized Official of:

Department of Transportation

Name: Peter E. Stamnas

Title: Director of Project Development

Signature and Date:  3/13/19

By An Authorized Official of: the New Hampshire Governor & Executive Council

Name: _____

Title: _____

Signature and Date: _____

EXHIBIT A

A. **Project Title:** Improved Practices for Determining the Infiltration Characteristics of Soils for Design of Stormwater BMPs (SPR Project #26962)

B. **Project Period:** Governor and Council approval through June 30, 2021

C. **Objectives:**

Soil infiltration data are utilized by the NH Department of Transportation (NHDOT) to assess the suitability of a site for various stormwater best management practices (BMPs) and to properly size and design a treatment area. With the recent issuance of EPA's final Municipal Separate Storm Sewer System (MS4) permit rules, the need for such testing is expected to increase.

In order to estimate infiltration rates, the NHDOT currently utilizes a variation of the borehole infiltration test prescribed in the NH Department of Environmental Services (NHDES) Alteration of Terrain (AoT) rules using conventional geotechnical drilling equipment. Existing testing protocols are labor intensive and time consuming, often taking 4 hours or more to complete a single test interval (depth). This is particularly inefficient if multiple depths require testing, e.g. if the preferred "bottom of practice" has not been established. In addition, the existing test method may not replicate field conditions and is prone to missing important features in the soil profile. Other available tests either require a constant head that is difficult to maintain in the field or have limitations associated with the effective depth of the test or the level of the groundwater table. Research is needed to evaluate alternative methods and improve Department practices to allow for more effective design of BMPs.

A permeaför device, originally developed in France, has been identified as a potential alternative to current practice. The permeaför is an in-situ hydraulic profiling tool that provides a quick estimate of the permeability profile of soil layers and can be adapted to conventional drilling equipment.

The objectives of this research are as follows:

1. Review available permeaför drawings, adapt design features to be compatible with NHDOT equipment and operations, and fabricate a prototype for further evaluation in the field.
2. Compare the performance of the permeaför alongside existing test method.
3. Recommend and implement design modifications as a result of initial testing.
4. Provide a workable permeaför device suitable for implementation on NHDOT projects.

D. **Scope of Work:**

The scope of work for this research includes the following major tasks, with primary responsibility indicated in parentheses:

1. Obtain available permeaför plans, shop drawings, and details. (UNH)
2. Recommend design changes to ensure compatibility with geotechnical drilling equipment operated by the NHDOT. (UNH/NHDOT)

EXHIBIT A

3. Fabricate one or more permeafor devices. A total of two (2) devices are anticipated as part of the research. It is suggested that a single device be fabricated for initial testing and the second device be fabricated to incorporate lessons learned after the initial testing. (UNH)
4. Procure required pumps, flowmeters, and other ancillary equipment. (UNH)
5. Calibrate the permeafor with grain-size analyses and permeability water tests performed in the laboratory. (UNH)
6. Identify field sites for testing. A minimum of three (3) sites will be evaluated, with multiple depths tested at each site. Sites will be chosen where NHDOT-obtained infiltration data has been collected or will be collected during the research. (UNH/NHDOT)
7. Conduct initial field testing at one or two sites. (UNH/NHDOT)
8. Review existing formula(s) used to convert field data to the Design Infiltration Rate needed for BMP design. (UNH)
9. Conduct final field testing at remaining sites. (UNH/NHDOT)
10. Recommend modifications to formula(s) used to convert field data to the Design Infiltration Rate needed for BMP design. (UNH)
11. Provide a final report summarizing the research and containing recommendations for implementation by NHDOT. (UNH)

E. Deliverables Schedule:

Tentative Schedule	2019												2020							
	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug		
1-Obtain permeafor detailed plans																				
2-Ensure compatibility with NHDOT drilling	■	■																		
3-Fabricate Permeafor		■	■	■	■															
4-Procure support equipment		■	■	■	■															
5-Calibrate Permeafor to lab results							■	■	■											
6-Identify field test sites		■	■																	
7-Conduct initial testing					■	■	■	■												
8-Review existing analysis methods							■	■	■	■	■									
9-Conduct final testing												■	■	■						
10.Revise testing and analysis methods														■	■	■	■	■		
11.Provide final report																	■	■		
Meet with Technical Advisory Group			■			■			■			■			■		■	■		

Quarterly summary reports will be submitted to the NHDOT Research Unit at the end of each calendar quarter (i.e. March 31, June 30, September 30, December 31). The research group will meet with the Technical Advisory Group quarterly or at major milestones. At these meetings, presentations of progress to-date and plans for continuing work will be presented to the TAG for comments and suggestions. A final report summarizing the research and containing recommendations will be submitted to the NHDOT at the completion of the project.

F. Budget and Invoicing Instructions:

UNH will submit invoices to State on regular UNH invoice forms no more frequently than monthly and no less frequently than quarterly. Invoices will be based on actual project expenses incurred during the

EXHIBIT A

invoicing period and shall show current and cumulative expenses. State will pay UNH within 30 days of receipt of each invoice: UNH will submit its final invoice not later than 60 days after the Project Period end date. State may withhold 10% of funds until receipt of final report from UNH. State will provide final payment within 30 days of receipt of the accepted final report, poster, and technical fact sheet.

Budget Items	
Salaries & Wages	45,744
Employee Fringe Benefits	2,880
Travel	1,500
Supplies & Services	35,045
Equipment	
Facilities & Admin Costs	26,643
Total	111,812

The Materials & Supplies include the following:

- Permeafor fabrication (2 probes) (1 probe for NHDOT, 1 probe for UNH)
- Pumps to supply water to the Permeafor during testing
- Flowmeters to control flow of water to the Permeafor (incl. software)
- Hoses, tools and other accessories

EXHIBIT B

This Project Agreement is funded under a Grant/Contract/Cooperative Agreement to State from the Federal sponsor specified in Project Agreement article F. All applicable requirements, regulations, provisions, terms and conditions of this Federal Grant/Contract/Cooperative Agreement are hereby adopted in full force and effect to the relationship between State and Campus, except that wherever such requirements, regulations, provisions and terms and conditions differ for INSTITUTIONS OF HIGHER EDUCATION, the appropriate requirements should be substituted (e.g., OMB Circulars A-21 and A-110, rather than OMB Circulars A-87 and A-102). References to Contractor or Recipient in the Federal language will be taken to mean Campus; references to the Government or Federal Awarding Agency will be taken to mean Government/Federal Awarding Agency or State or both, as appropriate.

Special Federal provisions are listed here: None or **Uniform Guidance issued by the Office of Management and Budget (OMB) in lieu of Circulars listed in paragraph above.**

COOPERATIVE PROJECT AGREEMENT

between the

STATE OF NEW HAMPSHIRE, Department of Transportation

and the

University of New Hampshire of the UNIVERSITY SYSTEM OF NEW HAMPSHIRE

- A. This Cooperative Project Agreement (hereinafter "Project Agreement") is entered into by the State of New Hampshire, **Department of Transportation**, (hereinafter "State"), and the University System of New Hampshire, acting through **University of New Hampshire**, (hereinafter "Campus"), for the purpose of undertaking a project of mutual interest. This Cooperative Project shall be carried out under the terms and conditions of the Master Agreement for Cooperative Projects between the State of New Hampshire and the University System of New Hampshire dated November 13, 2002, except as may be modified herein.
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- C. The work to be performed under the terms of this Project Agreement is described in the proposal identified below and attached to this document as Exhibit A, the content of which is incorporated herein as a part of this Project Agreement.

Project Title: Use of Smart Rocks to Improve Rock Slope Design (SPR Project # 26962Z)

- D. The Following Individuals are designated as Project Administrators. These Project Administrators shall be responsible for the business aspects of this Project Agreement and all invoices, payments, project amendments and related correspondence shall be directed to the individuals so designated.

State Project Administrator

Name: Deirdre Nash
 Address: NHDOT Bureau of Materials & Research
5 Hazen Dr. PO Box 483
Concord, NH 03302-0483
 Phone: 603-271-8995

Campus Project Administrator

Name: Karen Rooney
 Address: University of New Hampshire
Sponsored Programs Administration
51 College Rd. Rm 116
Durham, NH 03824
 Phone: 603-862-5412

- E. The Following Individuals are designated as Project Directors. These Project Directors shall be responsible for the technical leadership and conduct of the project. All progress reports, completion reports and related correspondence shall be directed to the individuals so designated.

State Project Director

Name: Krystle Pelham
 Address: NHDOT Bureau of Materials & Research
7 Hazen Drive, PO Box 483
Concord, NH 03302-0483
 Phone: 603-271-1657

Campus Project Director

Name: Jean Benoit
 Address: University of New Hampshire
Kingsbury Hall, W183
33 Academic Way
Durham, NH 03824
 Phone: 603-862-1419

F. Total State funds in the amount of \$100,249 have been allotted and are available for payment of allowable costs incurred under this Project Agreement. State will not reimburse Campus for costs exceeding the amount specified in this paragraph.

Check if applicable

Campus will cost-share _____ % of total costs during the term of this Project Agreement.

Federal funds paid to Campus under this Project Agreement are from Grant/Contract/Cooperative Agreement No. N/A from **USDOT Federal Highway Administration** under CFDA# **20.205**. Federal regulations required to be passed through to Campus as part of this Project Agreement, and in accordance with the Master Agreement for Cooperative Projects between the State of New Hampshire and the University System of New Hampshire dated November 13, 2002, are attached to this document as Exhibit B, the content of which is incorporated herein as a part of this Project Agreement.

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This Project Agreement and the Master Agreement constitute the entire agreement between State and Campus regarding this Cooperative Project, and supersede and replace any previously existing arrangements, oral or written; all changes herein must be made by written amendment and executed for the parties by their authorized officials.

IN WITNESS WHEREOF, the University System of New Hampshire, acting through the **University of New Hampshire** and the State of New Hampshire, **Department of Transportation** have executed this Project Agreement.

By An Authorized Official of:

University of New Hampshire

Name: Karen M. Jensen

Title: Manager, Sponsored Programs Administration

Signature and Date:

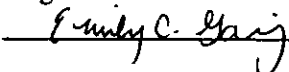
 2/28/19

By An Authorized Official of: the New Hampshire Office of the Attorney General

Name: Emily C. Goerdy

Title: Assistant Attorney General

Signature and Date:

 4/1/19

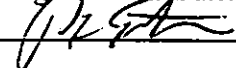
By An Authorized Official of:

Department of Transportation

Name: Peter E. Stamnas

Title: Director of Project Development

Signature and Date:

 3/13/19

By An Authorized Official of: the New Hampshire Governor & Executive Council

Name: _____

Title: _____

Signature and Date: _____

EXHIBIT A

A. Project Title: Use of Smart Rocks to Improve Rock Slope Design (SPR Project # 26962Z)

B. Project Period: Governor and Council approval through 06/30/2021

C. Objectives:

Rock slopes pose a hazard to the traveling public when weathering processes dislodge portions of the slope which then fall into the road. Current ditch design practice relies on design criteria developed decades ago in different environments with different rock types. Current hazard rating practice rates the rock slopes based on semi-quantitative measures using the Rockfall Hazard Rating System (RHRS). Both the design of new rock slopes and the hazard assessment of existing rock slopes need improvement to increase safety against rockfall, construct better engineered slopes and reduce short and long-term maintenance costs.

Preliminary work performed at UNH in collaboration with the NHDOT has shown that using a smart rock sensor equipped with a 3-axis accelerometer and 3-axis gyroscope, embedded in a natural rock can provide the necessary field response data to calibrate and revise existing rockfall simulation software models. To achieve this primary goal of improving rock slope design, several objectives need to be considered during this project:

1. Improve the current smart rock (SR) sensor to include altimeter capability. The use of wi-fi technology will also be investigated as a mean to acquire data without sensor removal from the test rocks.
2. Conduct multiple experiments with the smart rock at 10 rock cuts rated A or B according to the New Hampshire RHRS.
3. Analyze smart rock accelerometer and gyroscope data coupled with video recording of each experiment to extract information and parameters as input to current rockfall software packages.
4. Develop a design evaluation protocol for new and existing slopes using smart rock technology.

The next section described the approach to achieve these various objectives.

D. Scope of Work: To improve current rock slope design to reduce hazard to motorist on NH highways, the following tasks will be undertaken:

Task 1- Smart rock sensor improvements

The experiments recently carried out at Crawford Notch and I-93 by Disenhof (2018) used the first version of the smart rock designed for high accelerations normally encountered during rockfall. Previous tests have shown that minor improvements were necessary to ensure that each rockfall tests were properly recorded prior to doing additional drops at the same location. Improvements being considered include: altimeter data to help locate the rock elevation with time and for matching with video recordings, status test light using a transparent SR shell to ensure the SR is ready for testing between drops and, wi-fi or Bluetooth technology for data download. It is anticipated that several SR will be constructed (5 to 10) to allow cluster rock drops.

Task 2 – Laboratory testing

Experiments will be carried out in the laboratory to calibrate the smart rock sensor, by itself and embedded in a natural rock. The UNH shaking table and the machine shop lathes will be part of the tools used for this purpose. The experiments will also include a series of tests using various rock types equipped with the smart rock to evaluate the restitution coefficient between the rock and other surfaces such as concrete, asphalt, gravel, sand and turf.

Task 3 – Field experiments

Rockfall experiments will be carried out at approximately 10 rock cuts rated A or B according to the New Hampshire Rockfall Hazard Rating System. A tentative list is shown in Table 1.

Priority Rating	Route	Location	Height (ft)	Rock Formation	General Rock
A	93	AT MILE 97 NORTHBOUND - East side of I93 between MM 96.4 and 96.6 - AKA Barron Mtn Cut	140	Rangeley	Metamorphic
B	89	1.2m South of I89 SB Sutton Rest Area, at MP24.3, SW side, on curve, 2.7m S. of I89 Exit 10	25	Kinsman Granodiorite	Old Igneous
B	89 SB	0.4 MILES SOUTH OF MILE 40	36	Bethlehem Granodiorite	Old Igneous
B	125	WEST SIDE OF ROAD. ON UPHILL.	15	Eliot	Metamorphic
B	120	1m North of I89 Ext.18, CUT ON EAST AND WEST SIDES OF NH120.	35	Biotite Granite	Old Igneous
A	135	EAST SIDE OF NH135, AROUND CURVE, JUST North of MONROE US POST OFFICE, 0.6m South of #335r rock cut	30	Rangeley	Metamorphic
A	10	1/4m S OF GRAFTON COUNTY COMPLEX, W side of NH10, N of mp 119.8, just North of NHDOT North Haverhill shed #204	45	Pink Biotite Granite	Old Igneous
A	112	AT KANCAMAGUS PASS before scenic overlook (on left) cut on both sides of road. LIVERMORE/LINCOLN TOWN LINE	25	Conway	Mesozoic Igneous
A	16	JUST NORTH OF EXIT 13 ON SPAULDING TURNPIKE. BOTH SIDES OF ROAD.	45	Perry Mountain	Metamorphic
B	16	0.1 MILES SOUTH OF EXIT 17. BOTH SIDES OF ROAD.	33	Rangeley	Metamorphic
B	16	EAST SIDE OF ROAD AT MILE NUMBER 25. ACROSS FROM CUT NUMBER 118R.	34	Perry Mountain	Metamorphic
B	16	WEST SIDE OF ROAD. AT MILE MARKER 25.	60	Perry Mountain	Metamorphic
B	103	SOUTH SIDE. 1 MILE EAST OF TRAFFIC CIRCLE	25	Kinsman Granodiorite	Old Igneous
B	101	101/122 INTERSECTION ON-RAMP TO 101 WEST	30	Gneiss	Gneiss
B	31	0.7 MILES N OF OLD WILTON ROAD. 0.2 S OF GREENVILLE/WILTON TOWNLINE	20	Rangeley	Metamorphic
A	12	AT KEENE SURRY TOWNLINE CUT MAKES UP BOTH SIDES OF ROAD, AROUND CORNER	32	Ordovician Dome	Old Igneous
A	103	0.1m West from I89 Exit 9 ON NH103, North side of Road	60	Kinsman Granodiorite	Old Igneous
A	103	1m EAST OF BRADFORD-WARNER T/L, Both sides of NH103, 3.0 m EAST OF NH114/NH103 Jct., 3.7m West of I89 Exit 9	30	Kinsman Granodiorite	Old Igneous
A	3A	0.6m North of NH11 & NH3A Int., Both sides of NH3A - portion of rock formation the West side of Franklin flood control dam	55	Rangeley	Metamorphic
A	93 NB	EXIT 8 NORTHBOUND EXIT/ONRAMP	65	Gneiss	Gneiss
B	11	South of cut 072r, on east bound (west side) of roadway.	35	Winnepesaukee Tonalite	Old Igneous
B	112	ROUTE 112, SOUTHERN SIDE OF ROAD, 0.7 MILES EAST OF KANCAMANGUS PASS AND LINCOLN/LIVERMORE TOWN LINE.	20	Conway	Mesozoic Igneous
B	3	E. side of US3, on a curve, @ MP 139.4, 0.25m NE of Jct. w/ NH 141 & US3 (Const. slope/berm N. end of cut, @ MPs 139.2-139.4)	31	Littleton	Metamorphic

Table 1: NH Rock Cuts A and B Rated

The sites listed in Table 1 will provide a wide spectrum of rock types, slope types as it relate to roughness (i.e. developed by various construction methods; presplit vs production, and natural conditions), slope angles, landing/ditch layout (e.g. gravel, road, grass, etc.).

Experiments with the smart rocks will include natural rocks of various sizes and shapes. The sizes will be assessed using information from maintenance crews who may have documented the rock sizes during cleanup. The shapes will include rounded and bladed to match the existing software capabilities. If time and funding allow, a concrete rock will be fabricated using guidelines set by European rules for comparisons with other published experiments carried out by other research groups. Experiments using multiple rocks dropped at the same time and at the same location will be conducted to evaluate repeatability, dispersion and the effect of collision. For each rock cut, a minimum of 3 experiments at the same location and using the same drop technique will be carried out for statistical evaluation of trajectories and runout.

Each experiment with the SR will include video recording of the drop, measurement of lateral dispersion, estimates of rock bounce, measurements of runout, full acceleration and rotation spectra in 3-axes.

Task 4 – Analysis

For the 10 rock cuts selected for testing, a concurrent funded project using the STIC grant program will develop highly detailed 3D point clouds for these rock cuts. The results of the STIC work will serve as input for the smart rock models.

For each rockfall experiments, the acceleration and rotation data will be analyzed using Matlab in terms of time domain and frequency domain to assess which approach will yield the most useful information for design. The SR data coupled with the 3D point clouds will be used in software packages such as Rockfall, RAMMS, CRSP and others. The results from the software analyses will be compared to field observations. The reliability of these methods will be tested, and a documented approach will be proposed to improve their prediction capability.

Using the accelerations and rotation rates, the kinetic energy for each drop will be assessed and documented for future possible use in barrier design. All data will undergo a statistical analysis and present maximum, minimum and average values of runout and expected forces.

Task 5 – Recommendations

The work conducted as part of Tasks 1 – 4 will be used to develop the following:

- a) Design evaluation protocol for new and existing rock slopes
- b) Design charts – major revision of Ritchie’s model
- c) Develop parameters for rock analysis
- d) Collaborate with other research groups and populate existing databases

E. Deliverables Schedule:

Tentative Schedule	2019												2020											
	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec			
1: Smart rock improvements																								
2: Laboratory testing																								
3a: Phase 1 Field testing																								
4a: Phase 1 Analysis																								
3b: Field testing																								
4b: Analysis																								
5: Recommendations																								
TAG Meetings																								
Report writing																								

Quarterly summary reports will be submitted to the NHDOT Research Unit at the end of each calendar quarter (i.e. March 31, June 30, September 30, December 31). The research group will meet with the Technical Advisory Group quarterly or at major milestones. At these meetings, presentations of progress to-date and plans for continuing work will be presented to the TAG for comments and suggestions.

F. Budget and Invoicing Instructions: UNH will submit invoices to State on regular UNH invoice forms no more frequently than monthly and no less frequently than quarterly. Invoices will be based on actual project expenses incurred during the invoicing period and shall show current and cumulative expenses. State will pay UNH within 30 days of receipt of each invoice. UNH will submit its final invoice not later than 60 days after the Project Period end date. State may withhold 10% of funds until receipt of final report from UNH. State will provide final payment within 30 days of receipt of the accepted final report, poster, and technical fact sheet.

Budget Items		
1. Salaries & Wages		46,039
2. Employee Fringe Benefits		2,880
3. Travel		6,000
4. Supplies & Services		21,734
5. Equipment		
Total Direct Costs		76,653
Facilities & Administrative		23,596
Total Project Cost		\$ 100,249

The materials and supplies include the following:

- 5 – 10 Smart Rocks (retained by NHDOT or UNH - TBD)
- Portable rock drill to core rocks in field
- Inflation packers to push larger rocks (if needed)
- High speed camera with tripod
- Analysis software

The service provider cost is to hire scalars to drop the SRs in unsafe zones.

EXHIBIT B

This Project Agreement is funded under a Grant/Contract/Cooperative Agreement to State from the Federal sponsor specified in Project Agreement article F. All applicable requirements, regulations, provisions, terms and conditions of this Federal Grant/Contract/Cooperative Agreement are hereby adopted in full force and effect to the relationship between State and Campus, except that wherever such requirements, regulations, provisions and terms and conditions differ for INSTITUTIONS OF HIGHER EDUCATION, the appropriate requirements should be substituted (e.g., OMB Circulars A-21 and A-110, rather than OMB Circulars A-87 and A-102). References to Contractor or Recipient in the Federal language will be taken to mean Campus; references to the Government or Federal Awarding Agency will be taken to mean Government/Federal Awarding Agency or State or both, as appropriate.

Special Federal provisions are listed here: None or Uniform Guidance issued by the Office of Management and Budget (OMB) in lieu of Circulars listed in paragraph above.