Environment and Natural Resources Trust Fund
2018 Request for Proposals (RFP)

Project Title: **ENRTF ID: 185-F**

Advancing Streambank Protection Systems

Category: F. Methods to Protect or Restore Land, Water, and Habitat

Total Project Budget: $ 286,426

Proposed Project Time Period for the Funding Requested: 3 years, July 2018 to June 2021

Summary:

We request funding to build and test a prototype of a new bank protection system designed to protect stream banks, limit erosion and provide electricity in pristine ecosystems.

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Sponsoring Organization: U of MN

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Location

Region: Statewide

County Name: Anoka, Hennepin

City / Township: Minneapolis

Alternate Text for Visual:

Design principles, and potential deployment of a new bank protection system for Minnesota rivers

_____ Funding Priorities _____ Multiple Benefits _____ Outcomes _____ Knowledge Base

_____ Extent of Impact _____ Innovation _____ Scientific/Tech Basis _____ Urgency

_____ Capacity Readiness _____ Leverage _______ TOTAL ______%

ADVANCING STREAM-BANK PROTECTION SYSTEMS

I. PROJECT STATEMENT

RATIONALE: There is a high price tag to stream restoration projects, up to $1,200 per foot in urbanized areas, as compared to the 10 times more affordable, traditional rip-rap stream bank protection systems at a cost of $30-$120 per foot. In more rural environments costs per mile of restoration are more contained but still in the $100,000-500,000 range (e.g. Mission Creek, Amity Creek, Chester Creek). In fact, there are no real alternative solutions, between the large stones of rip-rap protection and the more holistic stream naturalization practice, guaranteeing an easy, smooth access to water, while protecting side-banks from erosion.

GOAL: The proposed research project focuses on the design and development of a new bank protection system able to operate in rivers of variable size and flow rate, preventing side bank erosion while extracting energy, at no environmental costs.

TECHNICAL DETAILS: This technology is based on a horizontal baffled wheel partially embedded in a bank protection system, placed where the stream flow is more energetic, i.e. at the outer bank of meandering channels. While the flow sustains the wheel rotation and continuously produces electric energy, the stream velocity near the bank is reduced, along with the sidewall erosional rate.

The intellectual property is currently protected under provisional patent #U011.0279US0 filed through the UMN Office of Technology and Commercialization. We recently received $150,000 in funding for the development of a reduced scale model and for preliminary experimental testing. However more support is requested here to advance experimentation, build and test a full scale prototype.

Several elements of novelty have been guiding our design and patent application: the partial exposure of the device to the flow guarantees high performance; keeping the gearbox and the generator enclosed with the river bank ensures that major electrical components will be out of the water and accessible, reducing deployment costs, maintenance costs, and failure risks, while providing easy connection to utilities. The turbine rotor will be built using an air-tight aluminum shell ensuring neutral buoyancy, thus minimizing bearing friction, as well and fatigue loads. The technology targets straight and single-thread meandering river channels common to the upper Midwest. It is envisioned to operate at river mid-depth, ensuring the capability to work with floating ice, debris, logs or canoes, as well as under high sediment transport and migrating bedforms. Thanks to the low tip velocity it will not be harmful to fish, beavers or other aquatic organisms. Several units can be staggered along the river meander outer bank achieving both goals of stabilizing the river channel, and lowering the energy bill for nearby houses, offices, or street illumination. **Because of the design dual purpose, we anticipate deployments in natural parks, riverfront properties or small communities or at the riverside of state, county or cycling roads.**

SPECIFIC ACTIVITIES: The main tasks that we will address in the project will enable the transition from technology development → performance assessment → prototyping → market-ready by 2022.

1) Quantify the ability of this technology to mitigate stream-bank erosion

2) Build a full scale prototype, deploy it, and assess its performance

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: *Measuring reduced erosion rates in laboratory experiments* **Budget: $116,000**

Experiments will be conducted in the Outer Stream Lab meandering flume at SAFL (see visual) featuring erodible sediment bed and side banks. Erosion measurements will be performed during the summer months by a PhD student and undergraduate students, under a wide range of flow conditions. In the winter months we will work on numerical simulation and performance tests in the indoor straight flumes. A few runs will be also completed outside, when the ice will form, to make sure that the device can operate efficiently throughout the year**.**

Outcome: ***Meandering flume advanced*** **testing**	**Completion Date**
1. Build numerical and physical small scale models with exchangeable blade designs	*March. 2019*
2. Quantify erosion rates in a meandering stream with and without the device in place; verify that erosion is not amplified in any downstream reach along the channel	*Sept. 2019*

3. Quantify power production at different flow rates and validate the numerical model	*March 2020*
4. Finalize the design using computational tests to systematically vary the baffle geometry	*Sept 2020*

Activity 2: Simulating, fabricating and field-testing a full scale prototype **Budget: $170,426**

The blade and rotor geometry optimized during Activity 1 will be scaled-up using numerical simulations and integrated with off-the-shelves mechanical components for prototype fabrication. **The device will be built in-house and tested in the SAFL Main Channel, with and without active sediment transport, and in real meandering rivers**. The Main Channel is 278ft long, 9ft wide, and able to operate with a mean flow velocity ~3ft/s, at depth up to ~5ft, thus representative of a small-medium scale straight river in Minnesota. Sediments can be recirculated guaranteeing equilibrium conditions during experimental tests designed to quantify both side-bank sheltering and power extraction capabilities. The channel bathymetry and flow velocity field will be monitored to ensure erosion protection at full scale, along the whole flume, and to optimize longitudinal spacing for multi-unit installations. The expected power output of each single device is within the 1-2KW range (enough for a small house, or more than 20 LED-based street light systems).

Outcome: Prototype construction and field testing	**Completion Date**
1. Build a prototype able to operate in a 0.5-1.5m depth channel	*February 2020*
2. Quantify the streamwise extent of the sheltering effects (field tests and simulations), the reduced shear along the downstream side banks (simulations), and the power harnessed from the flow at optimal performance (field test).	*September 2020*
3. Deploy the prototype in one or more Minnesota river(s): e.g. Rum River	*September 2021*

III. PROJECT STRATEGY

A. Project Team/Partners

The principal investigator (PI), prof. Michele Guala (SAFL, Civil Environmental and Geo- Eng., UMN), is the provisional patent holder, and the responsible for the product development, laboratory experimentation and field testing. Co-PIs prof. Lian Shen (Mechanical Eng., UMN and SAFL associate director) will contribute to the design and supervise the numerical simulation work; co-PI Jeff Marr (Associate Director for Engineering at SAFL) will contribute to the prototype fabrication and field testing. The team has expertise in stream restoration, river engineering, and sediment transport (Guala, Marr), computational modeling (Shen), mechanical engineering and structural design (Shen, Marr), renewable energy production (Guala, Shen).

B. Project Impact and Long-Term Strategy

The overarching goal is to provide a novel stream-restoration technology to rural communities, cabins, natural park infrastructure near water bodies in pristine ecosystems, integrating river bank protection with local energy production at the lowest environmental costs (invisible, inaudible).

With the multitude of streams and water front properties in Minnesota, **this technology could resonate with a large segment of environmentally conscious private residents**. Alternative options are stream bank stabilization by rocks and rip rap installations, in which our technology can be embedded, achieving additional sheltering and providing electricity for illumination, security and motions sensors, wildlife monitoring stations, wifi, and so on. **We believe there is an opportunity to deploy this technology** in pristine natural areas in Minnesota as well as remote communities, worldwide, with limited access to electric grid. We have a provisional patent and we intend to either **start a company or license the product**. In both cases this could bring **jobs** (site-specific design, installations, maintenance), and public recognition for **advancing carbon-free-emission technology**, **reduce erosion rates and contribute to water clarity in streams and lakes**.

C. Timeline Requirements

The project activities will be performed between September 2018 and September 2021. The milestones include reduced scale model tests (year 1-2) and a utility-scale prototype fabrication and field-tests (year 2-3). The design will be optimized using validated numerical simulations and laboratory experiments in flumes of different sizes.

2018 Detailed Project Budget

Project Title: Advancing streambank protection systems

IV. TOTAL ENRTF REQUEST BUDGET: $286,427.00 for 3 years

BUDGET ITEM	AMOUNT
Personnel:	$ 205,826
Michele Guala, PI (75% salary, 25% benefits); 11% FTE , 2 weeks per year for 3 years: Guala brings critically important expertise in experimental fluid dynamics and renewable energy a. He is the inventor of the device being patented and he will supervise all the tasks listed in the project activities with specific focus on laboratory and field sclae testing at SAFL. (2 weeks x 3 years = total $22,030)	
Jeff Marr, CO-PI (75% salary, 25% benefits); 7% FTE, 2 weeks per year for 3 years. J Marr is the associate director for applied research at SAFL. He has expertise in river dynamics, sediment transport , renewable energy, and project management. J Marr will supervise the prototype building and deployment and all field-scale operations. (2 weeks x 3 years = $18,308)	
Lian Shen, CO-PI (75% salary, 25% benefits); 7% FTE , 2 weeks per year for 3 years: Prof. Shen is an expert in computational fluid dynamics and renewable energy. He will supervise the postoctoral researcher in computational research. (2 weeks x 3 years = $25,484)	
Staff Engineers (78% salary, 22% fringe): 22% FTE (8 weeks per year) . will help the PhD student to build small scale models and the will be majorly involved in prototype fabrication and performance testing. Eric Steen will also be the main operator during the OSL deployment (year 1) and field deployments (year 3). [Eric Steen and C Ellis, 4 weeks each] ($68,544)	
Graduate student (59% salary, 41% fringe): One graduate students will be supported by IONE from Sept 2017 to Sept 2020, then he will be supported by this project for an additional year. He will be responsible for building the experimental model and prototype, collect data, and run numerical simulations to achieve the best performing design under reasonable flow hydrographs (activity 2). ($46,465)	
Outer Stream Lab operation (activity 1). Includes personel and supply: specifically Jessica Kozarek will be supported for 2 months in 2018 ($14,996); 3 undergraduate students will be supported during the summer 3 months ($10,000)	
Equipment/Tools/Supplies for laboratoy experimentation:	$ 35,600
Data acquisition system and supplies: General supplies for laboratory and field setups are quantified based on previous experience. Year 1 ($12,000), Year 2,3 ($10,000). The amounts will include 1) data acquisitionsystem (DAQ board and computer) for the laboratory and field experiment testing, 2) operating and maintenance costs of SAFL main channel and tilting bed flume (include updates on the laser scanner for bed topography measurements). These costs are split between **Activities 1 and 2**	
Outer Stream Lab (activity 1) : implementation of an erodible bank ($4,600) and bank reconstruction and replanting ($4,000) and a portion of yearly maintenance operations ($5,000).	
Prototype developement and field testing :	$ 41,000
Equipment: turbine components. **Activity 1:** A variable speed motor and drive and a torque sensor will be purchased for the laboratory scale turbine model ($5,000). Blade and torque producing elements will be rapid prototyped or 3D printed ($6,000, for various shapes). **Activity 2**: For the prototype we expect total component cost of approximately ($30,000)	
Travel: The field deployment will require extensive traveling to one or more in-state locations where the prototype will be deployed (to be determined). We expect 5-8 trips in the last year at (including tech support time). Standard trip reimbursement will follow UMN regulation (we anticpated $500 per trip)	$ 4,000
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	**$ 286,426**

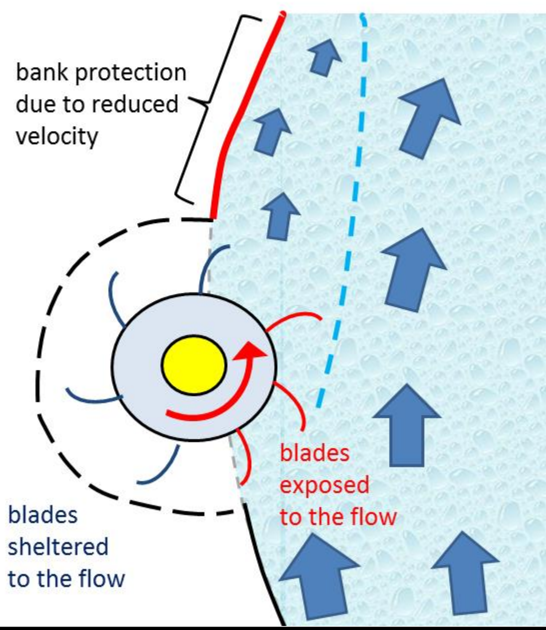
V. OTHER FUNDS

SOURCE OF FUNDS	AMOUNT	Status
Other Non-State $ To Be Applied To Project During Project Period: *IONE sponsored research covering 1 phD student per year for this project*	$ 150,000	*secured*

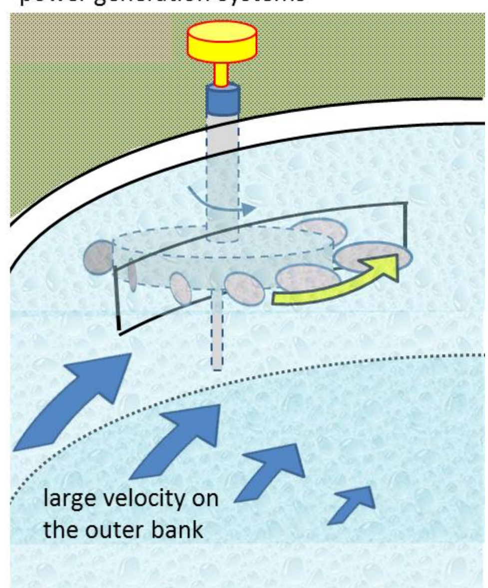
ADVANCING STREAM-BANK PROTECTION SYSTEMS

GOAL 1: STREAM BANK RESORATION	GOAL 2: ENERGY PRODUCTION
mitigate side bank erosion, limit sediment entrainment ensure water clarity	provide in-situ access to free electricity

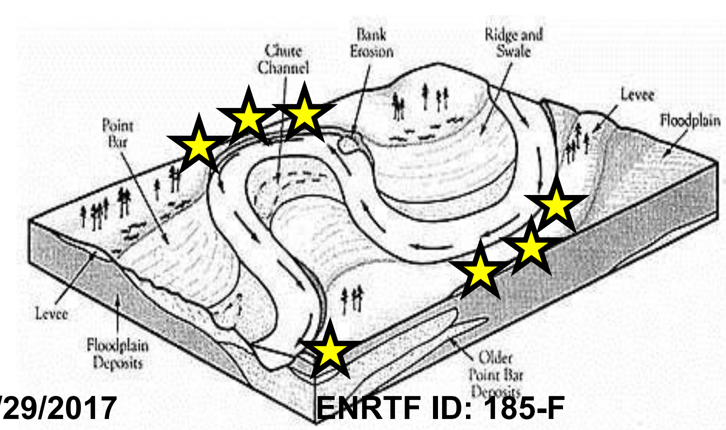
INTEGRATED IN-BANK PROTECTION SYSTEM



Non-submerged gear box, control, and power generation systems



Potential deployment location of single- or multi- unit ★ systems



Outer Stream Lab flume at SAFL

PROJECT MANAGER QUALIFICATIONS

Michele Guala, Assistant→Associate Professor, Department of Civil, Environmental and Geo- Engineering (CEGE), faculty member of the St. Anthony Falls Laboratory (SAFL), University of Minnesota, since Jan 2011.

Ph.D. Hydraulic Engineering, 2003, University of Padova, Italy
Laurea (BS+MS) Civil and Environmental Engineering, 1998, University of Genova, Italy

Professional experience
Postdoctoral fellow, California Institute of Technology, GALCIT, Pasadena , CA, 2008-2010,
Postdoctoral fellow at ETH Zurich (CH), Institute of Hydromechanics, 2003-2007

Awards/Recognitions
Recipient of the NSF CAREER award “Geophysical Flow Control” (2014-2019) fluid dynamics program.

Personal statement and expertise
I have a broad engineering and academic background ranging from River Hydraulics and Sediment Transport to Atmospheric Turbulence and Renewable Energy. This is reflected in my publications and in the academic institutions I have been working for, in my career. However, I primarily consider myself an engineer, an experimentalist, and an expert in the fluid mechanics of air and water. In the last four years I have been working on renewable energy systems for rivers. Recently, I hypothesized that stream restoration practice and energy harnessing can be combined. This is, in my opinion, a transformative conceptual model to lower the cost of river re-naturalization, while increasing the benefits of bank erosion control and renewable energy conversion. This idea is now part of provisional patent application filed through the Office of Technology and commercialization of UMN. I am currently advising 3 PhD students in my group and 1 undergraduate student; so far, I have graduated 2 PhD students. I have been recommended for tenure and promotion to associate professor in Civil Env. And Geo Eng. department (starting officially in September 2017)

TEAM DESCRIPTION
Michele Guala will supervise the turbine design, the performance quantification, and the sheltering effects on side bank erosion. He will be coordinating all the research activities, including documentation and reporting.
Lian Shen (professor in Mechanical Eng. UMN, and SAFL associate director) is an expert in computation fluid mechanics and fluid structure interaction with ongoing projects on offshore wind energy, ocean dynamics, air-water interface. He will supervise the computational work and design optimization.
Jeff Marr (SAFL director of applied research) has expertise in laboratory experiments and testing, river mechanics, sediment transport and field scale measurements. He will supervise prototype fabrication, field testing and deployment.

ORGANIZATION DESCRIPTION: St. Anthony Falls Laboratory, (www.safl.umn.edu)
The proposed research will be performed at SAFL using the Tilting Bed Flume, the Main Channel and the Outer Stream Lab facilities. These hydraulic channels are unique, in the sense that no other university in US has such a variety of large scale, highly equipped flumes for river morphodynamics (river bank protection) and sediment transport studies. The supporting engineering staff and researchers at SAFL have an outstanding experience in designing instruments, conducting laboratory and field measurements in rivers, and assessing the performance of renewable energy devices. Therefore SAFL is the best place to perform the proposed research activities and deliver the promised project outcomes. SAFL also organized more than 150 public tours per year, which provide great visibility to any work and scientific advancement accomplished here.