U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Standard Modular Hydropower Technology Acceleration

1.1.1.501

Hydropower Program

October 8, 2019

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Oak Ridge National Laboratory

Project Overview

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Project Summary

- A set of design objectives (the exemplary design envelope specification) that guide technology developers and hydropower stakeholders toward ecologically-compatible cost-optimized small hydropower technology innovations
- Execution of a multi-year research plan that includes site identification and classification, development of modeling capability for module and facility design optimization, and piloting of module and facility design, fabrication, and deployment

Project Objective & Impact

- Accelerate the development of new small hydropower assets using standardization and modularity of design, fabrication, and deployment to reduce costs and enhance value.
- Make new small hydropower technology and development sustainable and acceptable to stakeholders by including environmental functionality and compatibility as fundamental design objectives.

Project Information

Project Principal Investigator

Adam Witt (FY17-19)
Brennan Smith (interim)
Boualem Hadjerioua (FY19-21)

WPTO Lead

Tim Welch / Marisol Bonnet

Project Partners/Subs

Subcontracts:
- Knight-Piesold
- Small Hydro Consultants
- Univ. of TN-Knoxville

Project Duration

- Project Start Date: 10/1/2016
- Project End Date: 9/30/2021

Alignment with the Program

Hydropower Program Strategic Priorities

Environmental R&D and Hydrologic Systems Science

Big-Data Access and Analysis

- Technology R&D for Low-Impact Hydropower Growth
- R&D to Support Modernization, Upgrades and Security for Existing Hydropower Fleet
- Understand, Enable, and Improve Hydropower's Contributions to Grid Reliability, Resilience, and Integration

Alignment with the Hydro Program

Technology R&D for Low-Impact Hydropower Growth

- Enable the design and development of new Standard Modular Hydropower (SMH) technologies for both existing water infrastructure and new stream-reach development. This new approach to systems design for hydropower projects incorporates ecological and social objectives for river systems earlier in design processes
- Leverage new advancements in manufacturing and materials to dramatically lower costs of SMH components and systems designs

- The 2017 *Exemplary Design Envelope Specification* provides principles for SMH generation, passage, and foundation technology module designs to preserve river functionality.
- The 2017 *Modeling and Simulation Report* summarizes needs and available tools for SMH design.
- The SMH Explorer tool allows hydropower stakeholders to find sites with river functionality that matches the capability of SMH technology modules.
- The SMH project activities include additive manufacturing of SMH module components and development of new models of streamflow interaction with composite components and structures.

Project Budget

FY17	FY18	FY19 (Q1 & Q2 Only)	Total Project Budget FY17–FY19 Q1 & Q2 (October 2016 – March 2019)	
Costed	Costed	Costed	Total Costed	Total Authorized
$1,140K	$1,004K	$536K	$2,679K	$3,260K

- **SMH has stayed within budget during this peer review cycle**
- **A significant portion of FY19 funding (~$400K) provides ORNL technical support to FOA 1686 awardees (Littoral and Natel teams) for SMH facility design pilot efforts.**

Technical Approach

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Challenge: *New small low-head hydropower development success hinges on deeper cost reductions and greater environmental compatibility of technology than is presently available.*

Solution: *Achieve cost reduction through standardization and modularity. Achieve environmental compatibility by prioritizing stream functionality as design objectives for small, low-head hydropower facilities.*

Standardization–*commercially available advanced technology with pre-defined, validated, and published capabilities and impacts, including:*

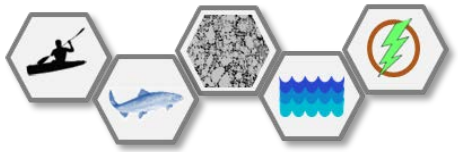
- siting methods;
- designs and design reviews;
- permitting, assessment, and licensing procedures;
- simulation models;
- manufacturing, transport, construction, and installation procedures; and
- commissioning, monitoring, and compliance procedures

... to minimize site specificity, project costs, and uncertainty.

Modularity–*compatibility and interoperability of standardized technologies in design and operation, including:*

- different module types in multiple arrangements to provide adaptability to classes of sites;
- multiple modules to scale up to optimal capacities;
- modeling and technology for inter-module monitoring and control; and
- major maintenance through module swap-out and economies of scale

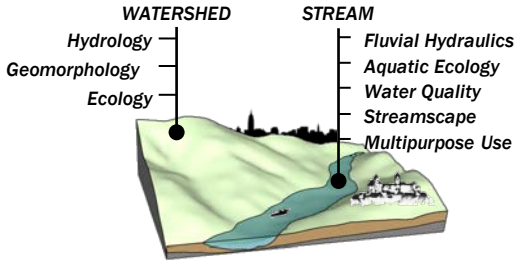
... to deliver energy and environmental benefits at many different sites.



Environmental Compatibility–*facilities and modules sited, designed, and operated for multiple compatible objectives, including:*

- stream functions identified and replicated by module and facility designs and
- monitoring and control systems to analyze and co-optimize stream and energy performance

... to maintain stream functionality, assure environmental compliance, and maximize public benefit.



Technical Approach

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Module R&D

- *SMH Exemplary Design Envelope Specification*
- *Environmentally-compatible cost-optimized modules*

Supporting Research

- *Fluid and structural dynamics simulations*
- *Reduced order models for design optimization*
- *Advanced materials and manufacturing technologies*
- *Detailed and refined module cost-performance models*

FOA 2080 awards

Market potential and cost thresholds for module technologies

Environmental objectives, criteria, and specifications

Module performance functions, environmental effects, cost functions

Siting and Facility R&D

- *SMH Explorer for nationwide site classification and identification*
- *WaterSHED model for multi-module flow allocation and module selection and sizing*

Supporting Research

- *Baseline design and cost estimates for three reference sites*
- *Hydraulic and hydrodynamics simulations of facility function*
- *Facility and inter-module cost models*

FOA 1836 awards

Future components of SMH:

- *Co-development with water uses*
- *SMH for non-powered dams*
- *SMH assessment and regulatory best practices*

SMH R&D Targets

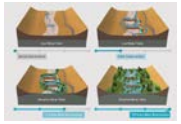
- *Environmental compatibility and acceptance*
- *Reduction in levelized cost of energy*
- *Reduction in capital expense*

Technical Approach

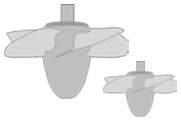
***SMH Co-Development Strategy**: Small hydropower technology development in isolation faces cost and acceptance challenges. Pairing hydropower development with designed improvements in environmental conditions or complementary uses of water can increase chances of success.*

- **Water quality improvement.** Can small modular facilities drive water quality improvements while generating energy?

- **Recreational park.** Can dual purpose hydropower and recreation facilities lead to greater acceptance from stakeholders?



- **Restoration.** Can small modular facilities help restore favorable hydrologic conditions and flow regimes while generating energy?

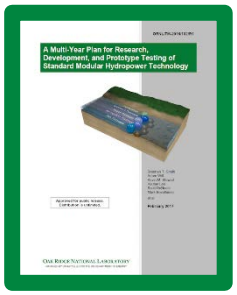


- **Low-flow at existing hydro.** Can a standard modular package improve low flow handling while generating energy?

- **Non-powered dam.** Can a modular energy/environmental/recreation solution provide the same benefit?

Image Sources: Creative Commons and Natel Energy (https://www.natelenergy.com/restoration-hydro/)

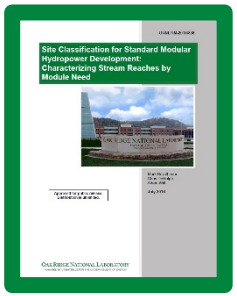
Technical Accomplishments: FY17-19 Technical Reports



A Multi-Year Plan for Research, Development, and Prototype Testing of Standard Modular Hydropower Technology

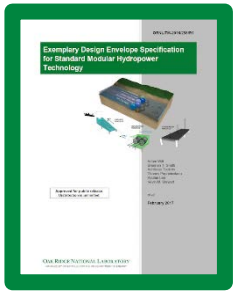
Presents a strategy for specifying, designing, testing, and demonstrating the efficacy of standard modular hydropower (SMH) as an environmentally compatible and cost-optimized renewable electricity generation technology.

Stream and ecological functionality, standardization, and modularity in hydropower design **are concepts that need definition, discussion, and demonstration within the hydropower community. ORNL SMH technical publications target that need.**



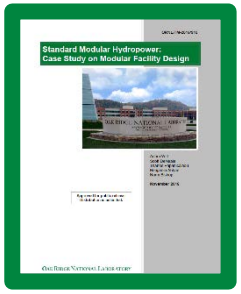
Technical Background on SMH Explorer Development

Describes the technical basis and results of SMH Site Classification research which are integrated within the SMH Explorer tool.



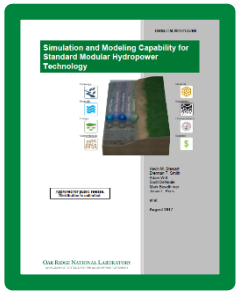
Exemplary Design Envelope Specification for Standard Modular Hydropower Technology

Offers a new paradigm for small hydropower technology development, based on the premise that standardization, modularity, and preservation of stream functionality must become essential and fully realized features of next generation hydropower technologies and project designs.



Standard Modular Hydropower: Case Study on Modular Facility Design

Outlines a new environmental design framework with the WaterSHED model for standard modular hydropower development, combining module design, systems design, performance modeling, and economic assessment.



Simulation and Modeling Capability for Standard Modular Hydropower Technology

Summarizes the concepts, use cases, needs, gaps, and challenges associated with modeling and simulating SMH technologies and presents recommendations for further modeling-related research and development needs to increase SMH deployment.

Technical Accomplishments: The SMH Explorer

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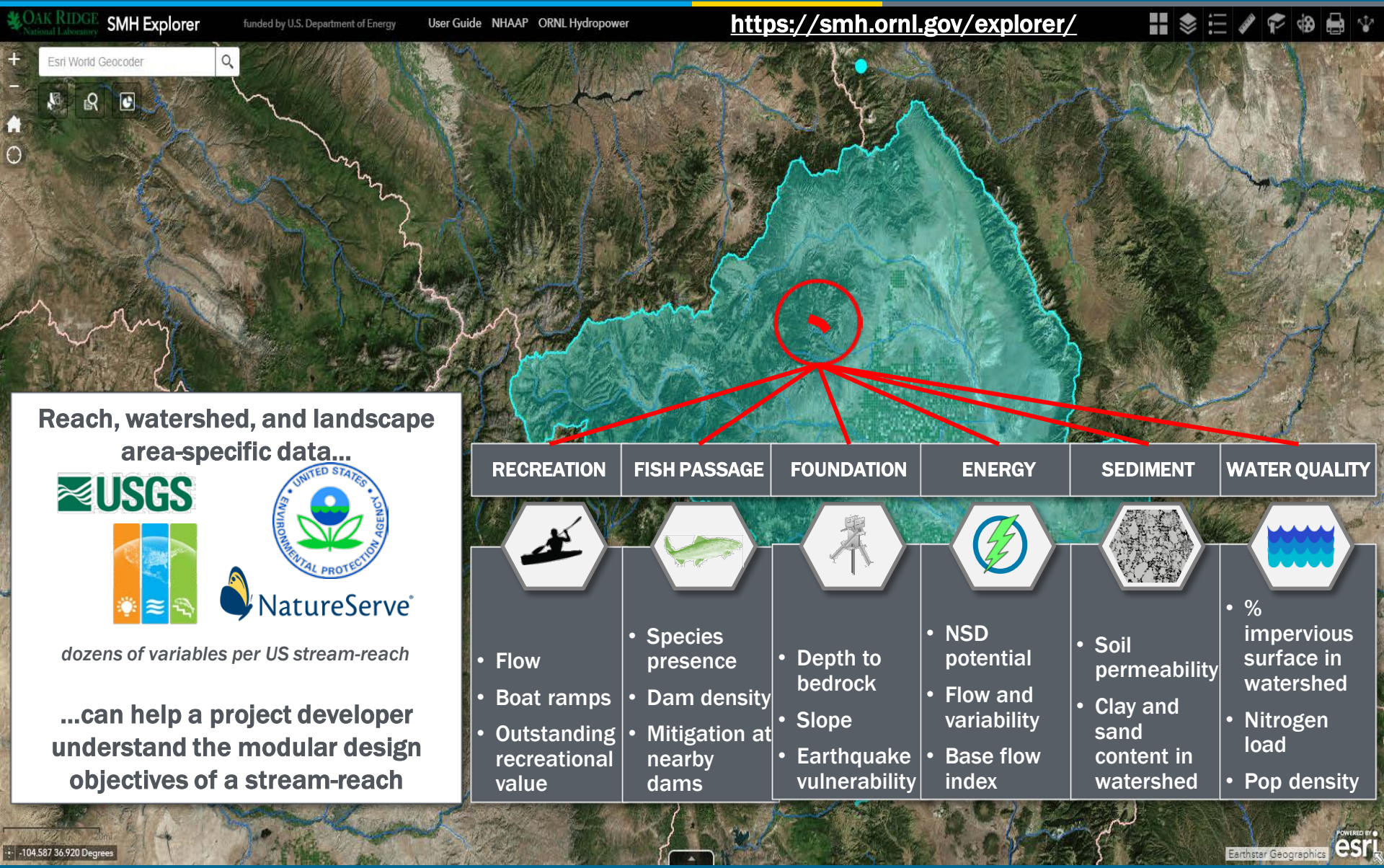

End-User Engagement and Dissemination Strategy

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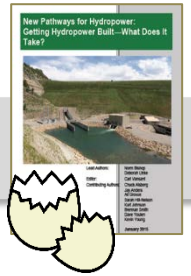
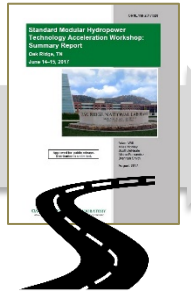
Initiation with Stakeholders



SMH was born out of the 2014-15 ***New Pathways for Hydropower Report*** co-sponsored by DOE/ORNL and the **Hydro Research Foundation** and co-authored by 11 hydro community leaders.

2014



Planning with Industry

- Aug-2015 ***Small Modular Hydro Manufacturing Workshop*** at ORNL
- 2016 formal SMH interviews with industry leaders
- June-2017 ***SMH Tech. Accel. Workshop*** at ORNL

ORNL workshops and interviews with industry leaders to establish baselines and vet proposed research pathways.

2015-17

Communications to Practitioners

- Sep 2017 Hydro Review article: *Making Small Hydro Development Affordable and Acceptable*
- Hydrovision 2017 paper: *How Standard Modular Hydropower Can Enhance the Environmental, Economic, and Social Benefits of New Small Hydropower Development*
- Hydrovision 2018 poster: *Modular Design-Based Multi-criteria Optimization for Identifying Hydropower Sites*

2017-19

http://smh.ornl.gov

Review by Technical Experts

ORNL engages industry experts to review technical reference reports that define key concepts and guide SMH technology designs prior to publication.

2016-18

Collaborative component designs, component manufacturing, and facility design with industry

2016-19

SMH researchers engage with hydro technology developers at the DOE Manufacturing Demonstration Facility at ORNL through technology collaborations funded by the DOE Advanced Manufacturing Office.

The *SMH Explorer Web Tool*, SMH Technical Reports, and *ORNL Hydro Cost Model* are the cited technical basis for industry funding opportunities from DOE:

- DE-FOA-0001836, Topic Area 1: Facility Design Concepts for Standard Modular Hydropower Development
- DE-FOA-0002080, Area of Interest 2a: Modular Technologies for Low-Head Hydropower Applications

2018-19

Convening in FY20

Industry and environmental leaders invited to serve on the SMH Innovation Advisory Group to help guide ORNL and FOA awardee collaborations

Progress Since Project Summary Submittal

- **Reference case finalizations**
  - Detailed designs and cost baselines for 3 reference sites (with Knight-Piesold)
- **Negotiated support for FOA 1836 - SMH Facility Design awardees**
  - Technical assistance for SMH siting and design
    - Littoral Systems – site identification and [standardized] environmental assessment
    - Natel Energy – fish exclusion technology assessment
  - Chartering and convening the SMH Innovation Advisory Group
  - Cost modeling for pilot SMH project designs from Littoral and Natel
- **First of multiple SMH co-development whitepapers**
  - Low-flow co-development class case study (with TVA and Small Hydro Consultants) with minimum flow national market assessment
- **Standardization and modularity for non-powered dam (NPD) development**
  - Preliminary scope of Exemplary Design Envelope Specification for NPDs
  - Preliminary scoping for NPD Explorer Web Tool

Future Work

- Technical support and integration of FOA (facility and module) awardee results into SMH concepts, reports, and tools.
- Potential expansion of role of Innovation Advisory Group
- SMH for non-powered dams (NPD)
  - Adaptation of Exemplary Design Specs for NPDs
  - SMH NPD Explorer online tool
- Scoping, guidance, and tools for SMH co-development classes
  - Standardization and modularity applied to sites/opportunities where energy and environmental/socioeconomic enhancement are complementary
  - Case studies, module-based technologies, modeling tools, and cost-benefit analyses for co-development classes:
    - Water Quality Enhancement
    - Aquatic Recreation Park
    - Stream Restoration
    - Low-flow Releases at Existing Hydropower Facilities
- Best practices for realizing the benefits of SMH design and technology in environmental assessment and regulatory proceedings