Standard Modular Hydropower Technology Acceleration

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About the Water Power Technologies Office

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

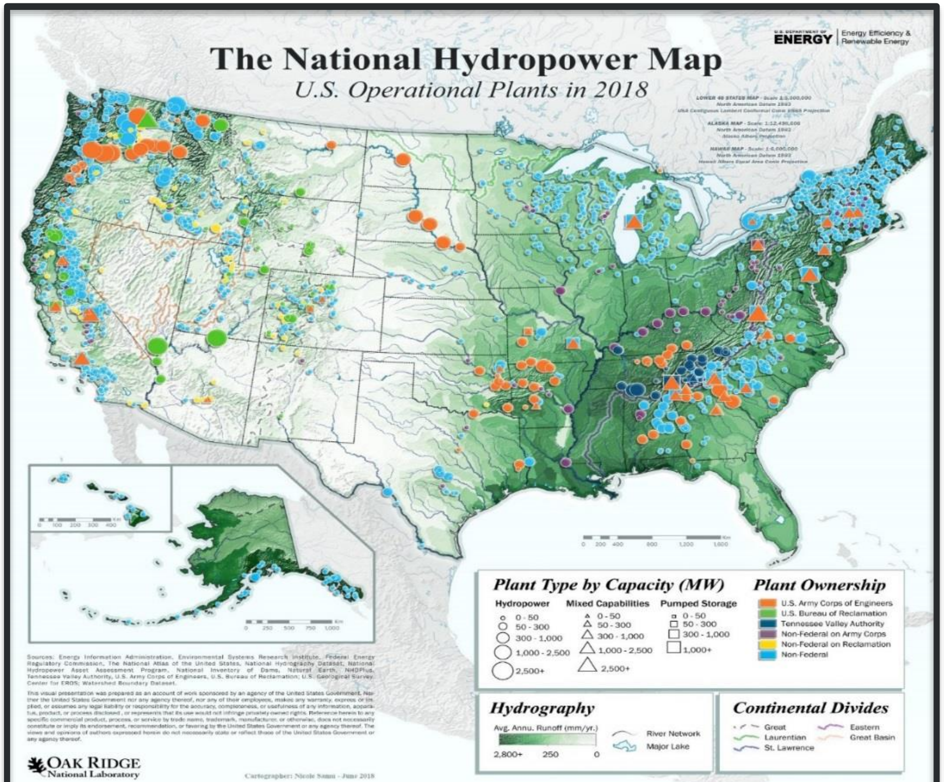
WPTO **invests in early-stage research** to accelerate development of innovative water power technologies while **ensuring that long-term sustainability and environmental issues are addressed**.

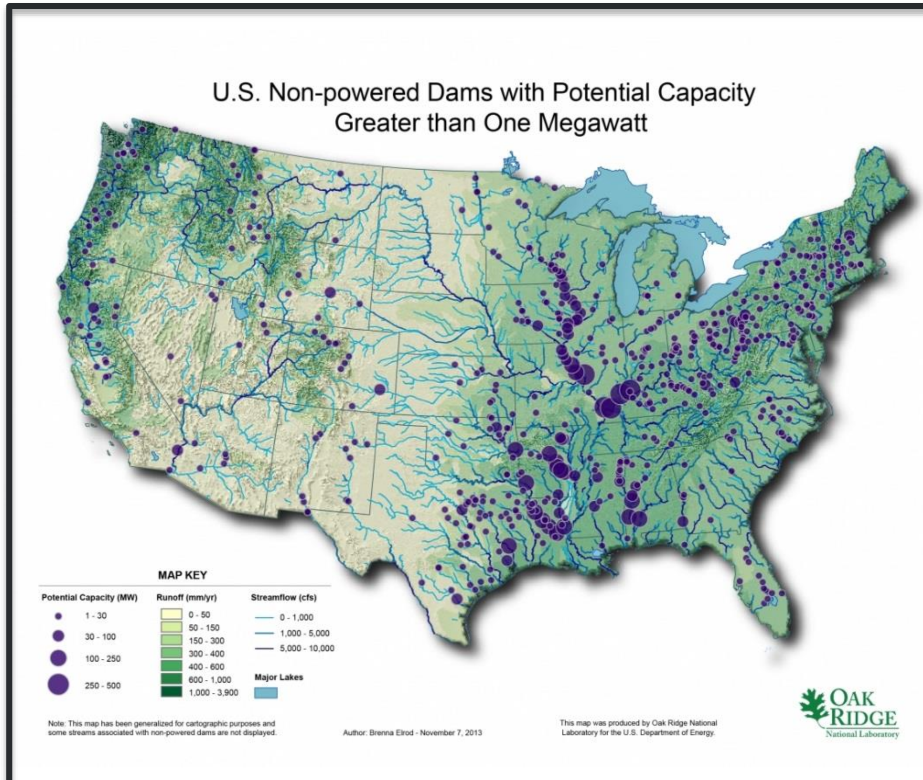
WPTO supports efforts to **validate performance and grid-reliability** for new technologies, develop and increase accessibility to **necessary testing infrastructure**, and evaluate **systems-level opportunities and risks**.

WPTO aggregates, analyzes and disseminates **relevant, objective, technical information** on water power technologies and related issues to stakeholders and decision-makers.

HYDROPOWER HIGHLIGHTS

- **80 GW of hydropower capacity – 7% of U.S. capacity**
- **Of the ~77,500 non-powered dams – over 50,000 have the potential to be powered, adding 12GW of capacity**
- **Greenfield development (when excluding federally protected lands, etc.) represents over 65GW of capacity**
- **Nearly 1.5 GW of capacity added in the last decade but new opportunities often limited by regulations, high costs, and environmental concerns**





Hydropower in the U.S.

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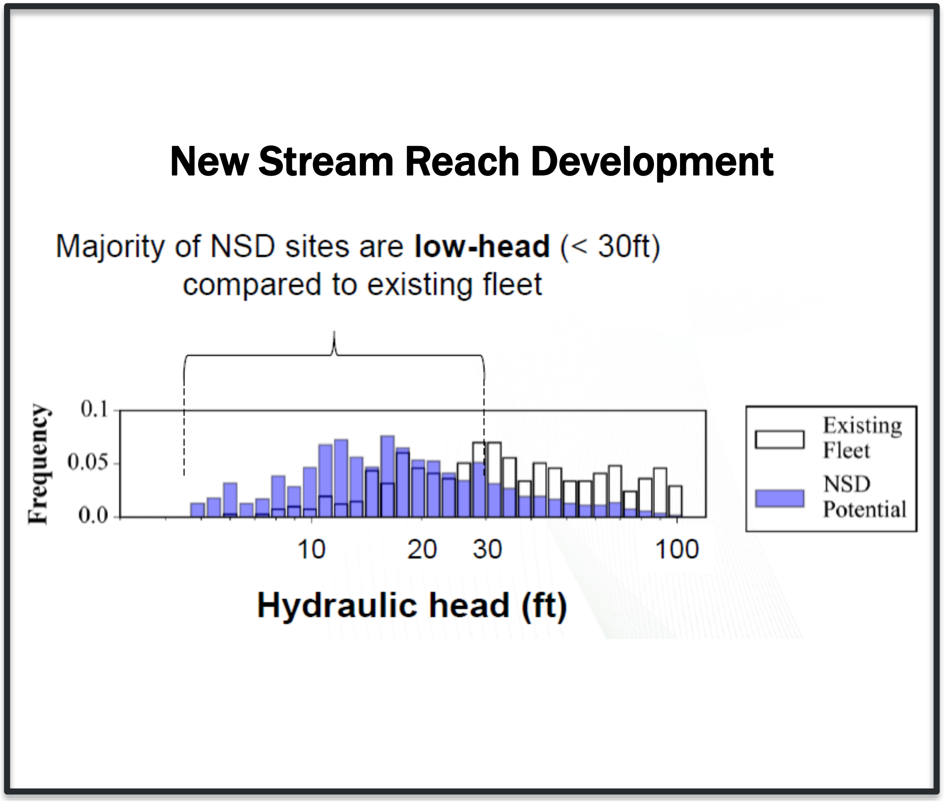

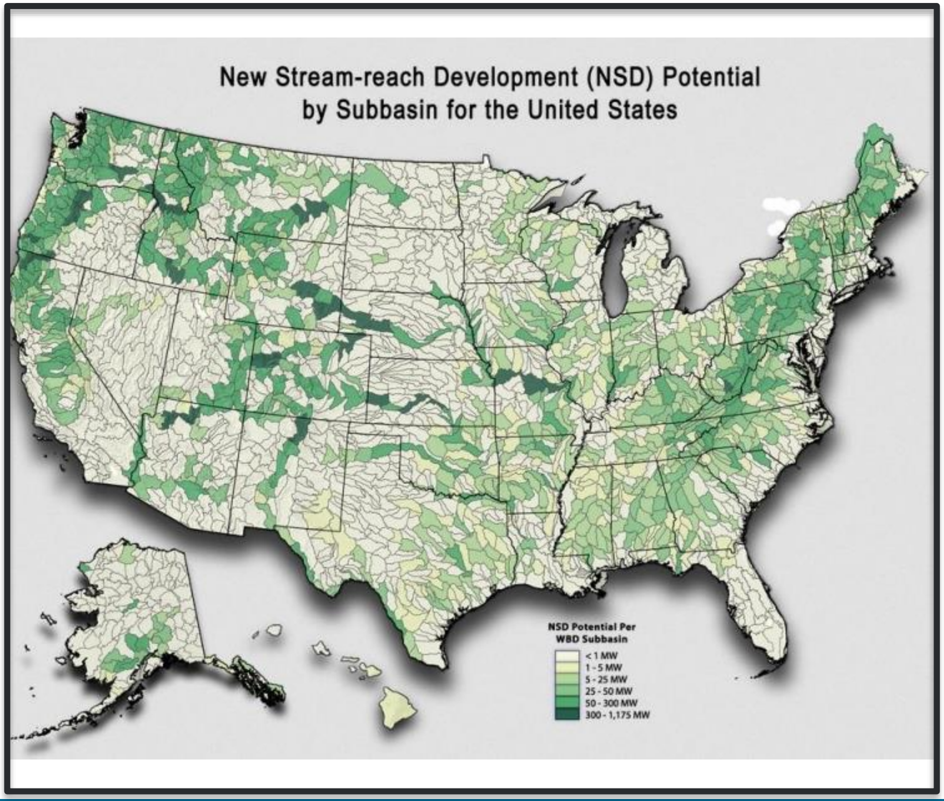

Digitalization Alignment with the WPTO

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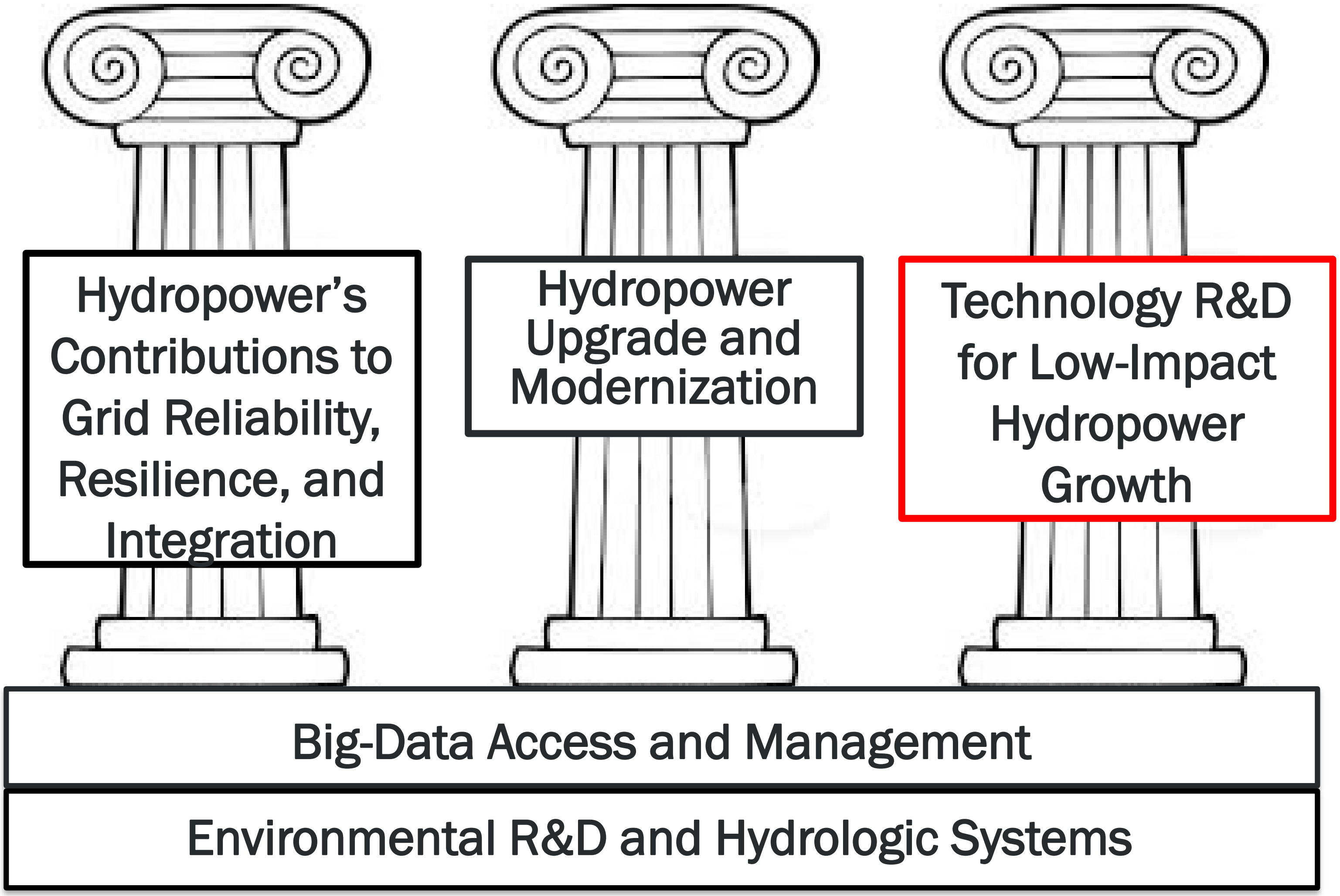
Hydropower Program Strategic Priorities



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:*

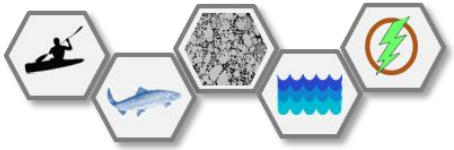
- siting methods;
- designs and design reviews;
- permitting, assessment, and licensing procedures;
- simulation models;
- manufacturing, transport, construction, and installation procedures; and
- commissioning, monitoring, and compliance procedures

... 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

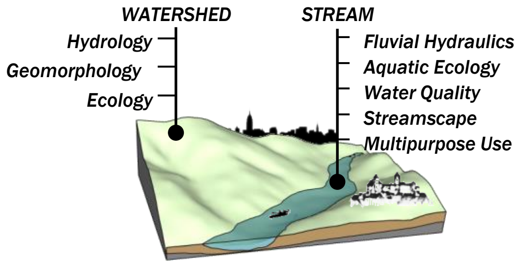
... to deliver energy and environmental benefits at many different sites.



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

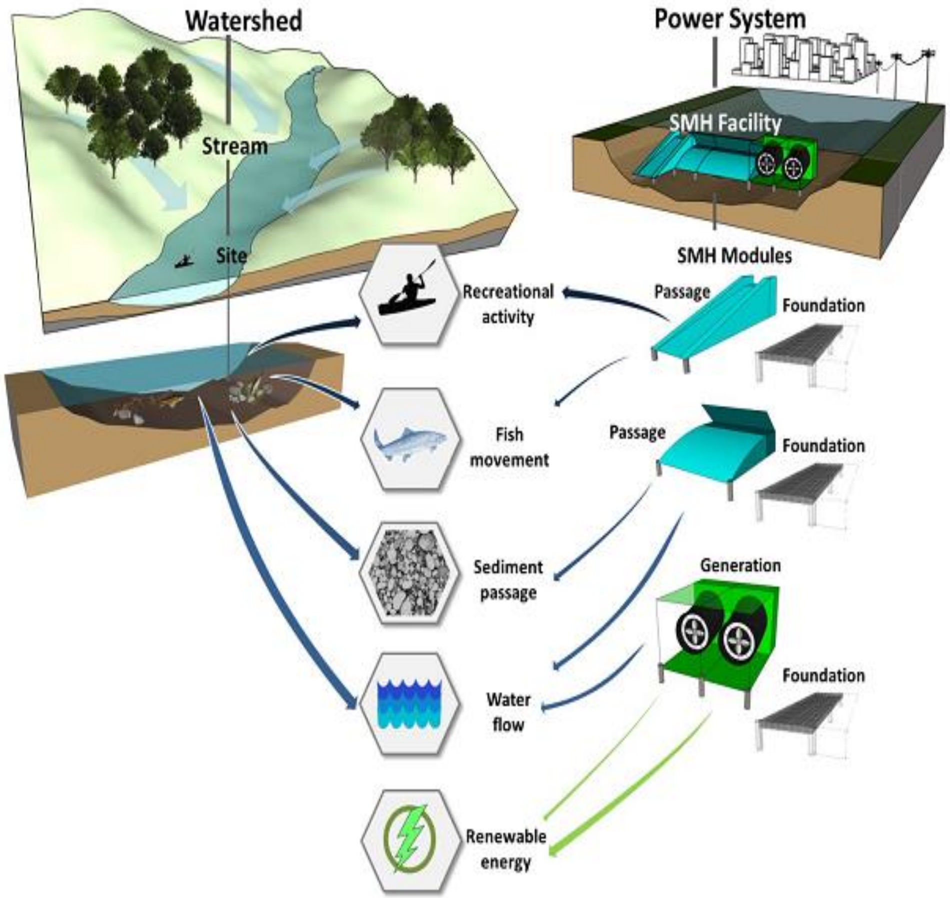
Future components of SMH:

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

SMH R&D Targets

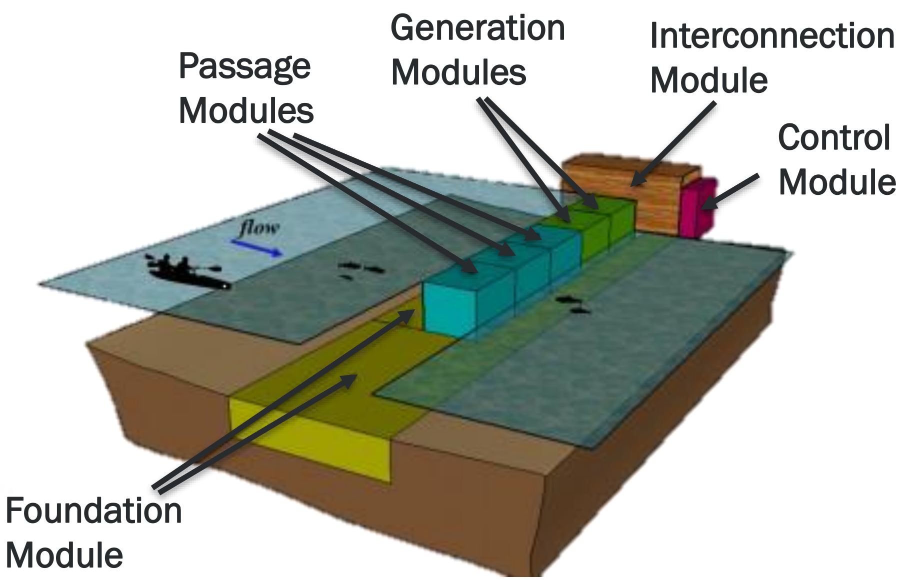
- ***Environmental compatibility and acceptance***
- ***Reduction in levelized cost of energy***
- ***Reduction in capital expense***

Hydropower Modular Design: A New Approach to Designing and Developing New Hydro



The SMH module concept is to:

- Reduce a hydroplant to its basic components
- Define module performance characteristics
- Promote the development of new capabilities and knowledge
- Facilitate system deployment



Module Objectives

Recreational Activities
- Set Difficulty
- Safe Entrance/Exit
- Pass Across SMH
- Foundational Integration
- Emergency Rescue

Fish Movement
- Attract Fish
- Pass Across SMH
- Foundational Integration
- Safe Fish Exit

Sediment Passage
- Intake Sediment
- Pass Across SMH
- Foundational Integration
- Release Sediment

Water Passage
- Safe Passage
- Passage Needs
- Entrance Hydraulics
- Foundational Integration
- Maintain Hydraulics

Energy Generation
- Take in Flow
- Energy Conversion
- Release Flow
- Prep Electrical Power
- Foundation Integration

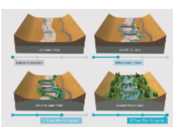
SMH Description:
- Functional Requirements
- Functional Relationships
- Module Key Inputs
- Module Performance
- Module Key Inputs

Technical Approach

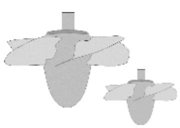
<u>SMH Co-Development Strategy</u>: Small hydropower technology development in isolation faces cost and acceptance challenges. Pairing hydropower development with designed improvements in environmental conditions or complementary uses of water can increase chances of success.

- **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/)

Future Work

- **Technical support and integration of FOA (facility and module) awardee results into SMH concepts, reports, and tools.**
- **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**

Thank you for your attention.

Questions?

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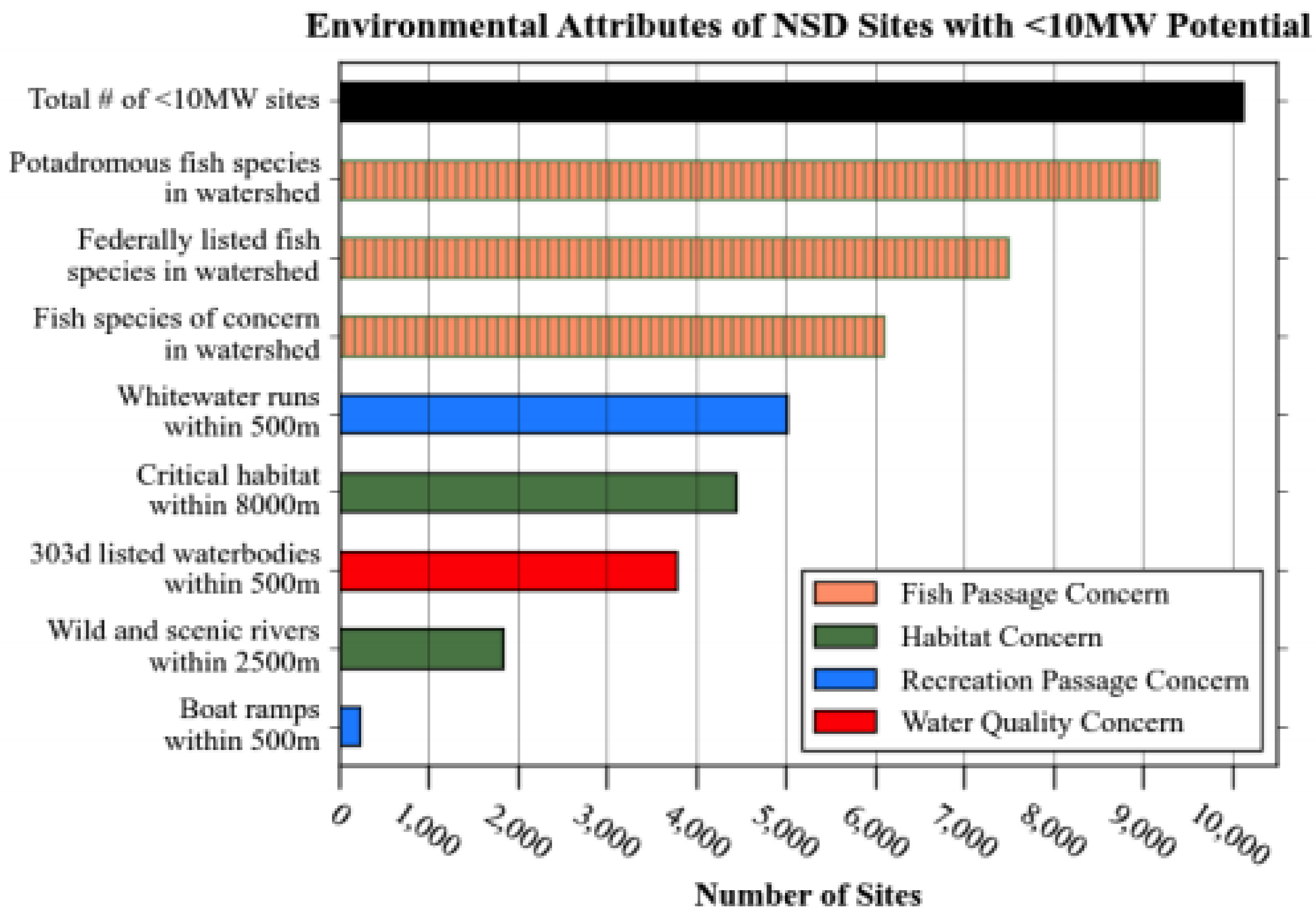
How WPTO's Hydropower Portfolio Aligns with EERE Priorities: Affordability



The SMH Explorer

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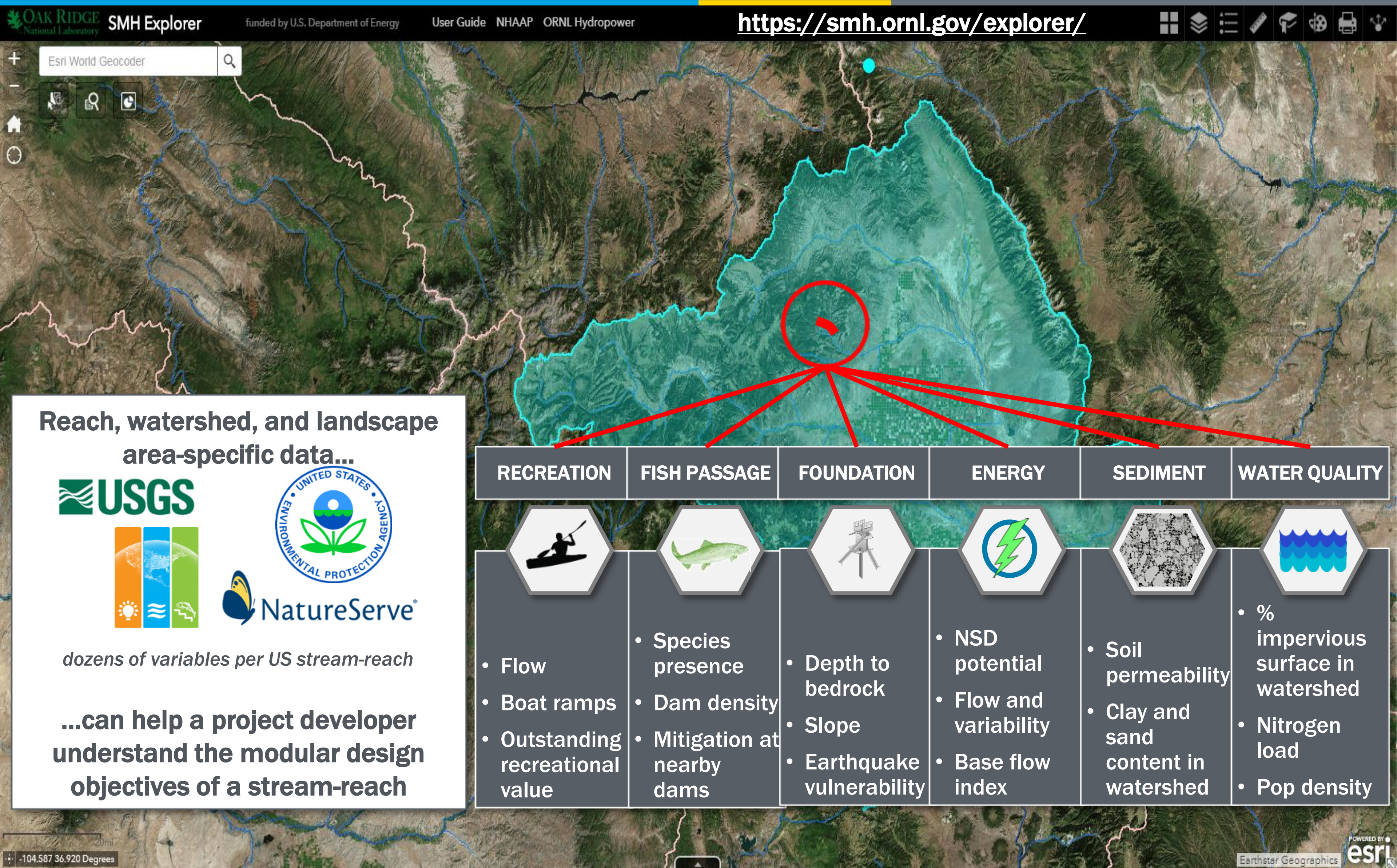

Reach, watershed, and landscape area-specific data…

USGS

United States Environmental Protection Agency

NatureServe

dozens of variables per US stream-reach

…can help a project developer understand the modular design objectives of a stream-reach

RECREATION	FISH PASSAGE	FOUNDATION	ENERGY	SEDIMENT	WATER QUALITY
• Flow • Boat ramps • Outstanding recreational value	• Species presence • Dam density • Mitigation at nearby dams	• Depth to bedrock • Slope • Earthquake vulnerability	• NSD potential • Flow and variability • Base flow index	• Soil permeability • Clay and sand content in watershed	• % impervious surface in watershed • Nitrogen load • Pop density

Generation Module

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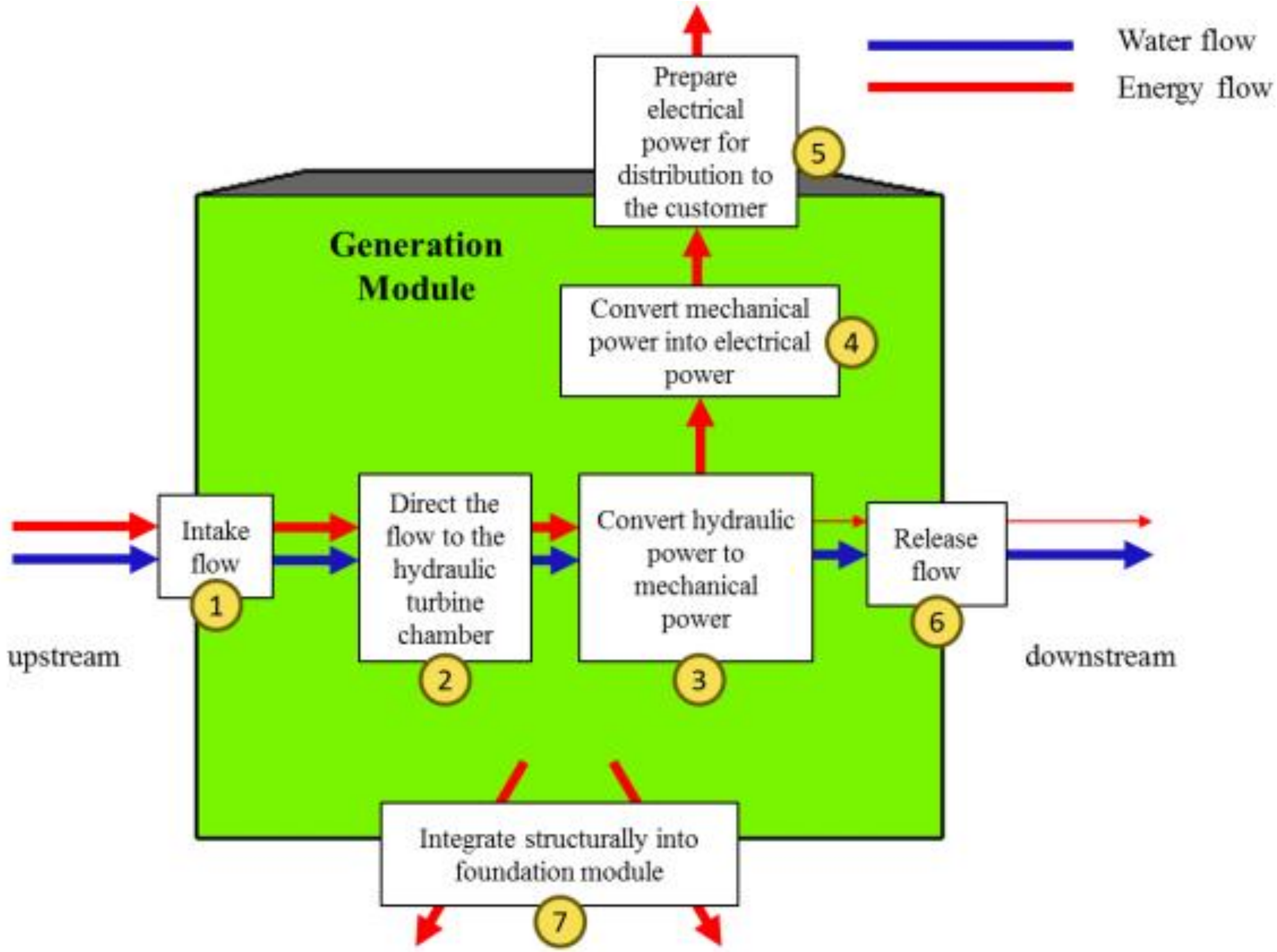
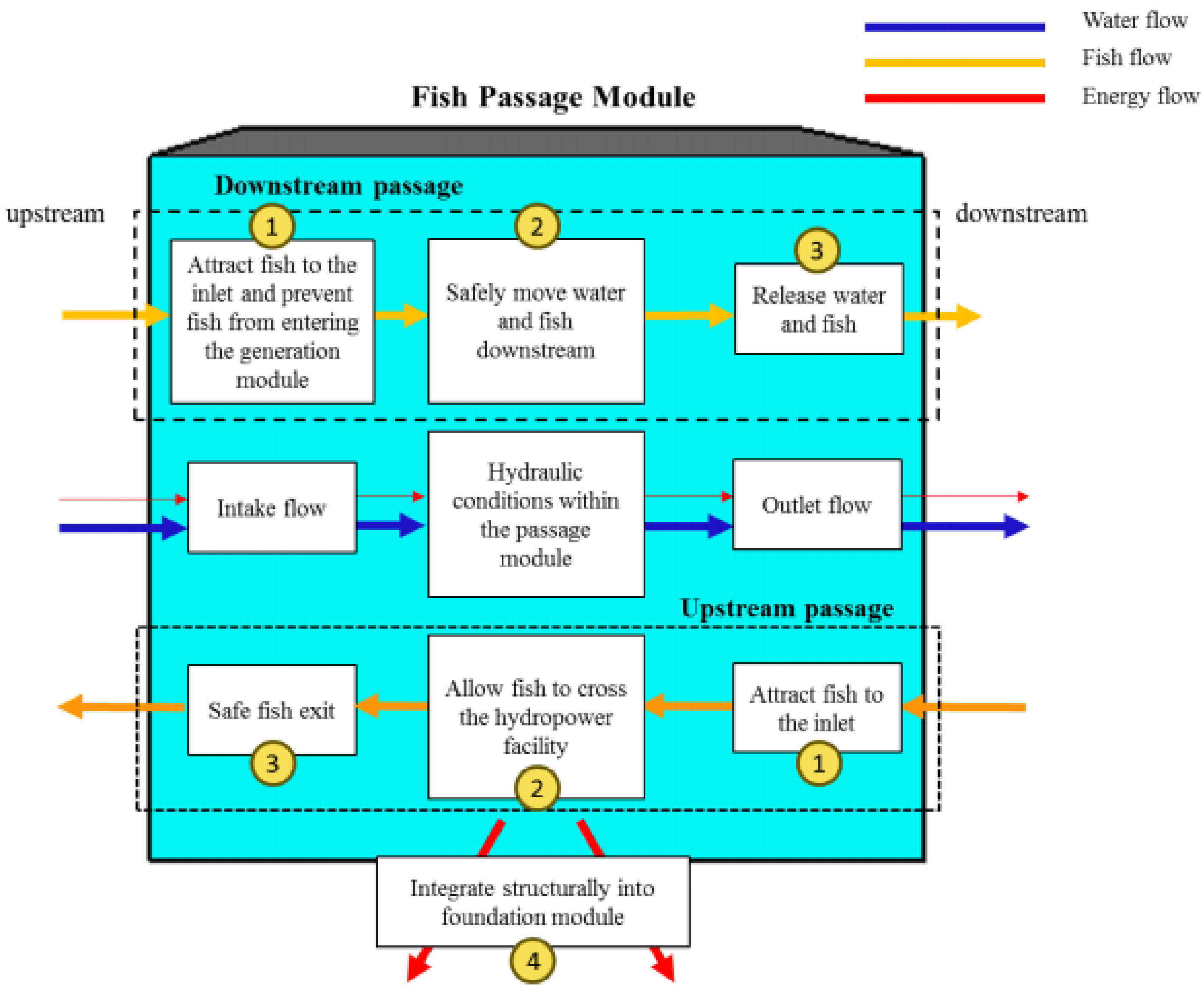


Figure 3. Conceptual schematic of the specific objectives of a generation module.

Fish Passage



Recreation Passage

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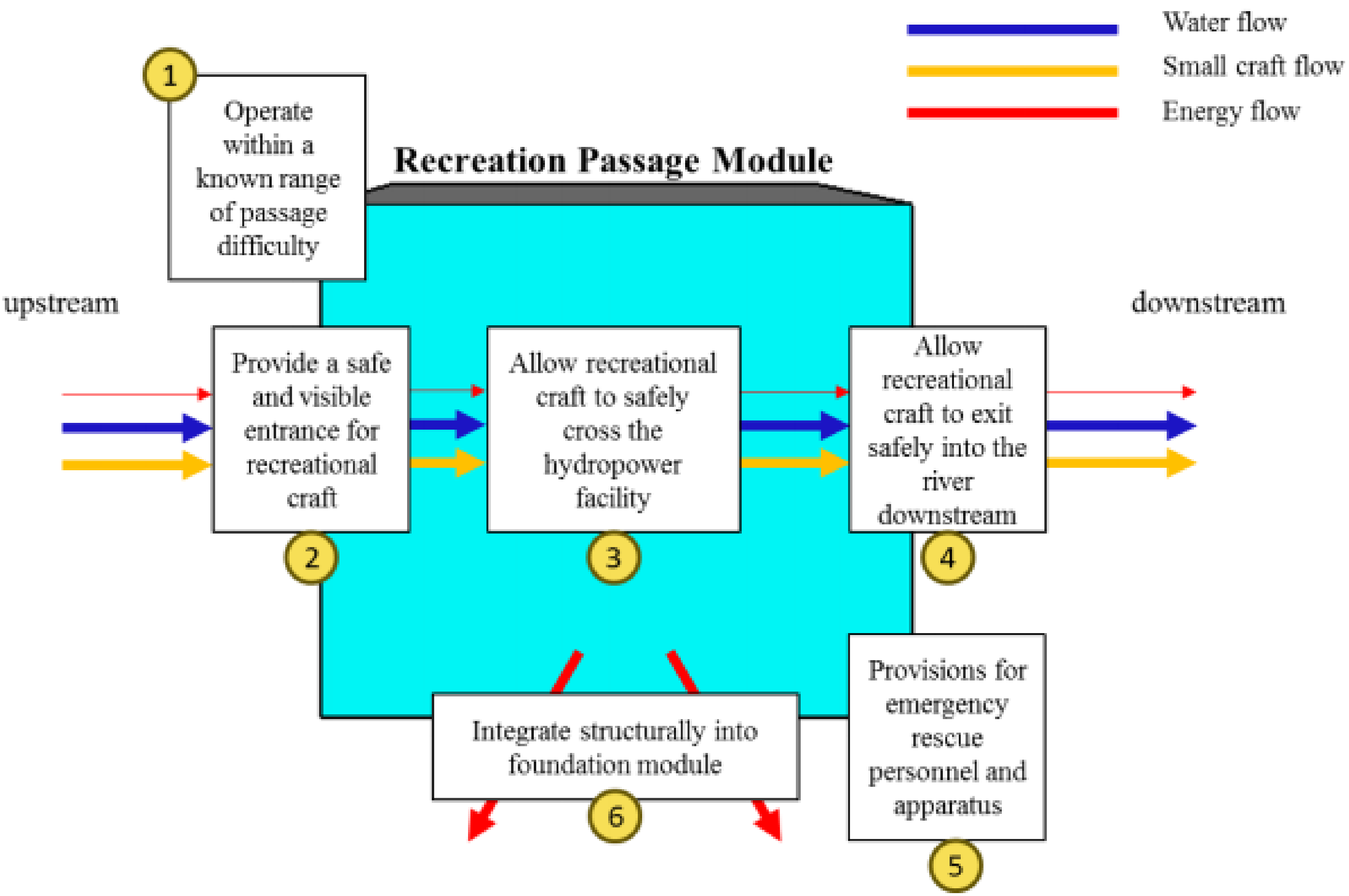

Figure 33. Conceptual schematic of the specific objectives of a recreation passage module.

Sediment Passage

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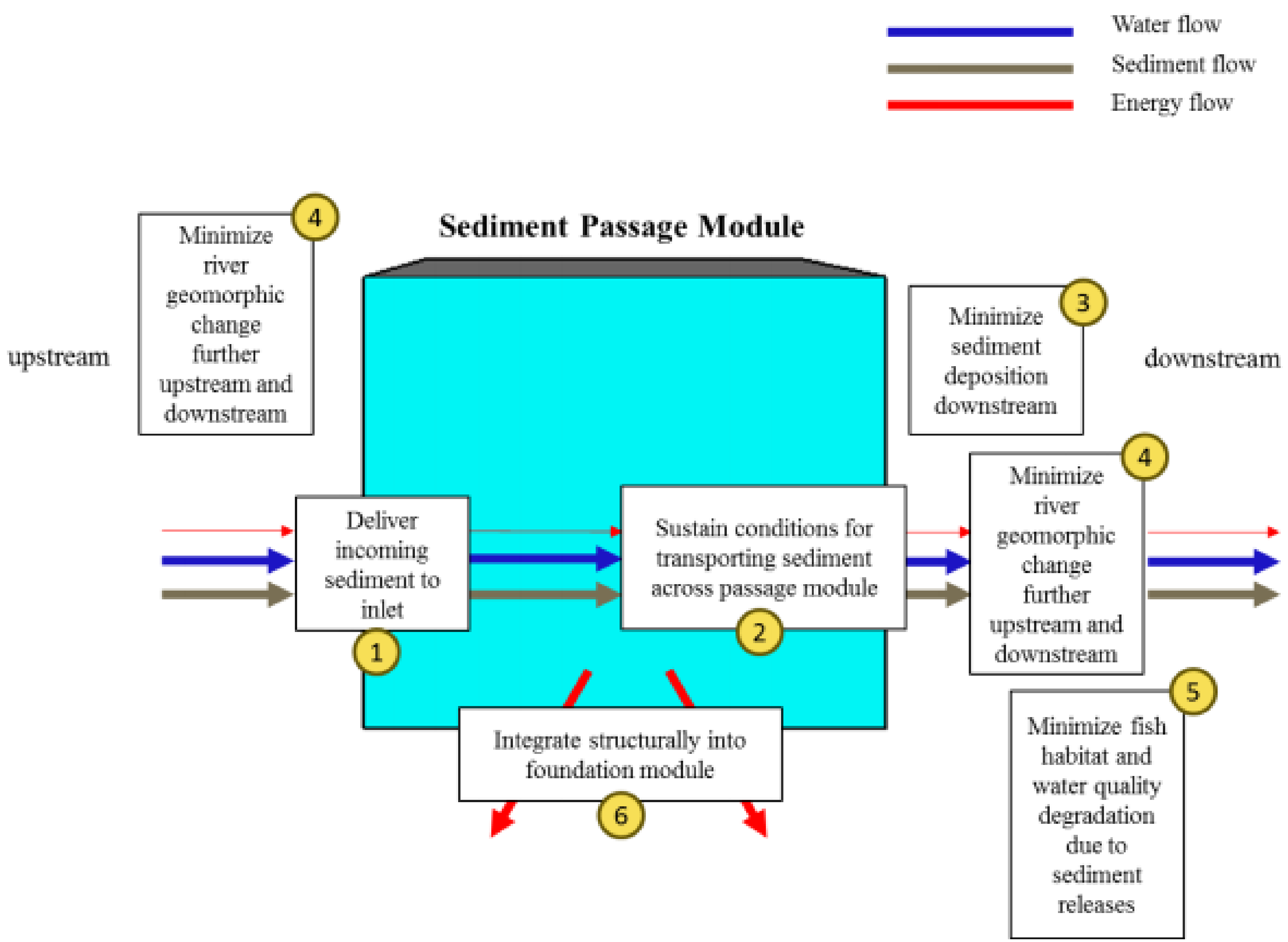

Figure 25. Conceptual schematic of the specific objectives of a sediment passage module.

Water Passage

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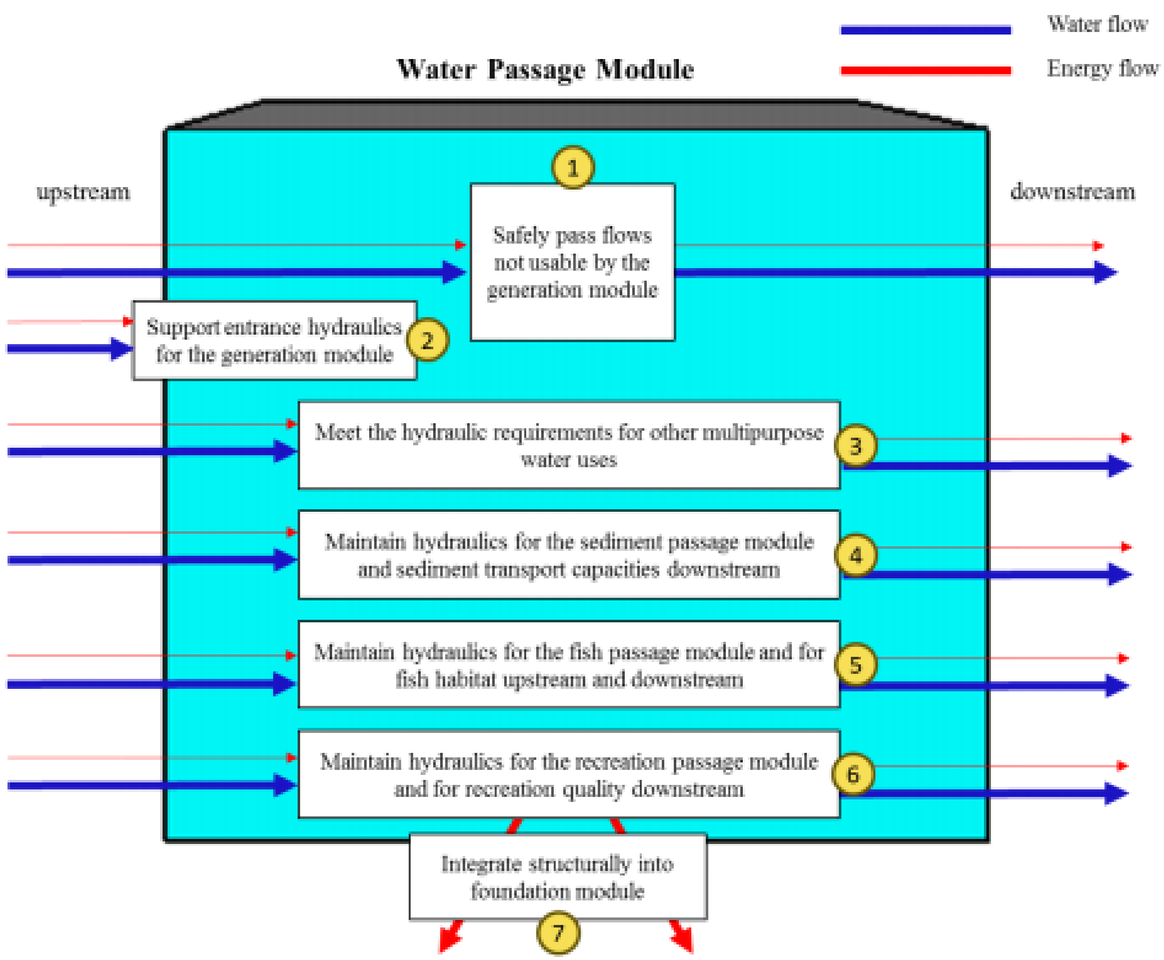

Figure 42. Conceptual schematic of the specific objectives of a water passage module.