

Final Technical Report

Cover Page

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BUILDING A BRIGHT FUTURE: The Hydro Research Foundation's Fellowship Program



December 2015

Executive Summary

The Hydro Fellowship Program (program) began as an experiment to discover whether the hydropower industry could find mechanisms to attract new entrants through conducting relevant research to benefit the industry. This nationwide, new-to-the-world program was started through funding from the Wind and Water Power Technologies Office of the Energy Efficiency and Renewable Energy (EERE) Office of the Department of Energy (DOE). Between 2010-2015, the Hydro Research Foundation (HRF) designed and implemented a program to conduct valuable research and attract new entrants to the hydro workforce. This historic grant has empowered and engaged industry members from 25 organizations by working with 91 students and advisors at 24 universities in 19 states. The work funded answered pressing research needs in the fields of civil, mechanical, environmental, and electrical engineering, as well as law, energy engineering and materials innovation. In terms of number of individuals touched through funding, 148 individuals were supported by this work through direct research, mentorship, oversight of the work, partnerships and the day-to-day program administration.

The intended outcome of the funding was to place students in industry by conducting relevant search. The findings of this report are that the funding achieved these outcomes. With a placement rate in the industry of 77% of participating students, when combined with all 43 Fellowship students submitting findings to advance the industry's understanding of pressing research topics, the grant funding was a resounding success.

The numbers support the outcome that, not only did the funding directly impact the 91 students/advisors and 25 participating industry organizations, there are now more professors teaching and conducting hydropower research, with the addition of 11 new professors, teaching assistants and graduate researchers continuing to stimulate academic interest in hydropower. With the advisors funded, along with the addition of new academic champions, there are now at least 48 professors continuing to find solutions and teach hydropower in their classes. This means that the funding has spread to academia by spurring interest in cutting edge problems. Of the alumni who joined the industry beyond the 11 in academia, 12 joined the private industry, 8 took government positions related to hydropower, and 2 joined national labs.

"I have recently had the privilege to work with [alumni] Dr. Adam Witt and Oak Ridge National Laboratory on a project for the national utility in Thailand related to sustainable infrastructure for the Mekong River. Adam's insight, judgment, technical knowledge, communication skills, and maturity make me very proud to have been a small part of the HRF Fellowship Program."

*-Patrick March, Hydro
Performance Processes*

All of the research findings are housed both at the Foundation's website, www.hydrofoundation.org as well as on OpenEI http://en.openei.org/wiki/Main_Page. Due to the vast volume of research that was conducted under this award, the Foundation was not able to include all findings in this report, but have placed them in two public spaces for use by the industry and future researchers.

The high quality of the students and their research is also evident. Students, alumni, and their advisors have received national and international awards and recognition for their technical work and the work of students to date has been cited 220 times by subsequent researchers.

Based on the program results, it is clear that the funding achieved the hoped-for outcomes and has the capacity to draw universities into the orbit of hydropower and continue the conversation about industry research and development needs. The Foundation has fostered unique partnerships at the host universities and has continued to thrive with the support of the universities, advisors, industry and the DOE. The Foundation has demonstrated industry support through mentorships, partnerships, underwriting the costs and articulating the universities' support through in-kind cost sharing. The Foundation recommends that future work be continued to nurture these graduate level programs using the initial work and improvements in the successor program, the Research Awards Program, while stimulating engagement of academia at the community college level for operations and maintenance workforce development.

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Introduction

Hydro Research Foundation

The Hydro Research Foundation was established in 1994 with two principle objectives: to facilitate research and promote educational opportunities that communicate the value of hydropower. With this mission the Foundation is actively working in each area. The primary purpose of Hydro Research Foundation is "Advancing hydropower's role in our clean energy future through research and education." As such, the HRF encourages the development of projects and programs from the hydropower industry at all levels.

Through the years, the HRF has developed several projects and programs by several different approaches. These programs have ranged from multi-year, research and development projects like the Advanced Hydro Turbine System - involving federal/private cost-sharing mechanisms - to educational programs ranging from the K-12 materials to stimulate interest in hydropower. The Foundation has also held research and development forums, modeled Malad River Trout passage, and held Hydro Power Contests for students.

Most recently the Foundation has undertaken projects to advance small hydropower through work with Oak Ridge National Laboratory through creating an online technology catalog, a policy report and a summary of new technology ideas to advance small hydropower penetration on the grid. The Foundation's main focus the past several years has been on graduate level research programs which include the Fellowship Program detailed here and the ongoing Research Awards Program.

Goals of Program versus Actual Accomplishments

Original Program Goals:

- Develop and manage a collaborative effort involving a broad spectrum of industry and academic organizations.
- Award Fellowships to approximately 27 graduate and doctoral level students for one-to-three year periods of study, which shall include conducting relevant research in the fields of hydropower-related engineering and environmental sciences.
- Widely publicize the ongoing and completed research at national forums and through electronic media.
- Develop career entry opportunities for graduates into the hydropower industry and academic organizations.
- Develop the next generation of hydropower specialists to respond to one-half of the current hydropower workforce that is eligible for retirement within five years.
- Provide full accountability for the expenditure of project funds to the Department of Energy and the public.

Actual Accomplishments:

- Established and executed a collaborative process using a team of 14 steering group members 24 partner universities, 54 students, 37 academic advisors, 36 industry mentors, 7 Foundation consultants, and the HRF board members. A total of 148 individuals were involved in the program.
- Created a national network of 1,200 contacts at 125 universities to foster applications from 52 unique universities resulting in 43 Fellows selected, and the program demonstrated a competitive award process.
- Awarded 43 Fellowships, nearly doubling the original goal of number of students funded.
- Supported 11 additional students under the program between June 2015-September 2015 who will continue their research under the Research Awards Program.
- The funding reached 22 congressional districts in 19 states.
- Forty-three research findings completed. All students between 2010-2014 completed the agreed-upon research which developed innovative technology, advanced environmental mitigation, provided models for industry, and addressed cost-effective solutions to hydropower's most pressing needs.
- Beyond the 43 final findings, 71 presentations were made regarding the program and research and 33 publications beyond the research findings were made public through a variety of industry trade publications.
- To date, 40 of the Fellow's publications were cited 220 times by subsequent researchers.
- Received national and international publicity on the program.
- Developed career opportunities and internships for Fellows resulting in the placement of 77% of students in industry or continued hydropower related research.
- From this funding, 8 unique research centers of excellence within university departments were fostered in 7 states, where multiple students within that department were funded.
- All financial requests approved and reconciled to the cent. The program received and maintained clean audit results.

Steering Group Members

- **Linda Church-Ciocci**-National Hydropower Association
- **John Etzel**- US Army Corps of Engineers
- **Carol Goolsby**-Duke Energy
- **Dr. John Gulliver**- University of Minnesota
- **Dr. Paul Jacobson**- Electric Power Research Institute
- **Diane Lear**- National Hydropower Association
- **Patrick March**- Hydro Performance Processes Inc.
- **Kerry McCalman**- U.S. Bureau of Reclamation
- **Sonya Reiser**- Knight Piésold Consulting
- **Gerry Russell**- Weir American Hydro
- **Dr. Michael Sale**- Low Impact Hydropower Institute
- **Dr. Brennan Smith**- Oak Ridge National Laboratory
- **Carl Vansant**- HCI Partners
- **Dr. Larry Weber**- University of Iowa

Summary of Project in Review

Hydro Fellowship Program

The Hydro Fellowship Program was developed from the ground up in 2010 funding from DOE with the goals of developing a program that would stimulate academic interest in hydropower and gain new entrants into the field of hydro.

In the inaugural year of the program, the Hydro Research Foundation (HRF) assembled a Steering Group of 14 members from academic, industry and research organizations. The steering group members were the visionaries who developed the application and selection processes.

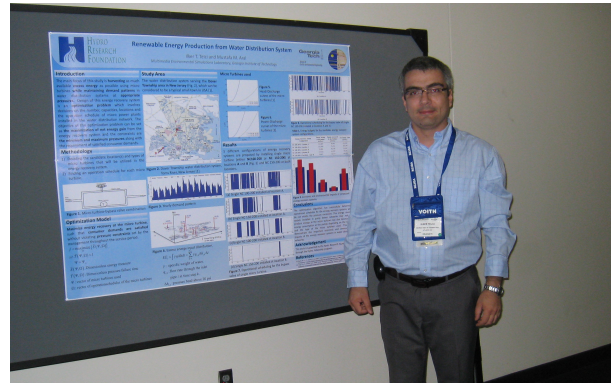
One of the most innovative aspects of this program is that the Steering Group, the HRF Board of Directors (Board), industry leaders and consultants worked to gather a list of over 60 topics of interest for funding. This list was vetted with industry, the National Hydropower Association's Research and Development Committee, DOE and the HRF Board for input and updates. This list represents the industry's research challenges. In 2012 this list was re-organized to reflect priorities among topics. This list was shared with the call for applicants so students and advisors knew the areas that were most desired for research. It was a valuable tool that was used for the program and to guide discussions on how to approach other pressing research needs within the industry. This list is available in Appendix I.

First Year of Program

During the first round of funding, applications were received from 34 universities and nine Fellowships were awarded at eight universities. Of these initial Fellows, 45% were master's degree students and 55% were doctoral degree students. The Fellows' areas of study were:

- Rock Scour Evaluation Using Block Theory and the Critical Key Block Concept
- Computational Fluid Dynamics Study to Examine the Effect of a Kármán Gait on Fish Locomotion
- Dynamic Hydrologic-Economic Modeling of Tradeoffs in Hydroelectric Systems
- The Effects of Climate Change on the Water Resources and Hydropower Production Capacity of the Upper Colorado River Basin
- Real-Time Forecasting and Hydropower Reservoir Optimization Using Sampling Stochastic Dynamic Programming
- Glacial Influences on Water Resources of the Eklutna Basin, Alaska
- Evaluating Internal Erosion in Earth Dams Using Non-Destructive Methods
- Modifying Hydropower Releases to Reduce Riverbank Erosion
- Development of a Technology to Predict Gas Transfer at Low and High Head Structures

The Fellows attended the HydroVision International 2010 Conference in Charlotte, North Carolina, where they participated in an educational session and a hydro facilities tour at Duke Energy. The facility tour exposed the Fellows to hydropower operations and real world issues facing the hydroelectric industry. It also afforded them the opportunity, as did the conference, to meet with industry professionals and secure information relative to their research. Each Fellow introduced their research topics at the Fellows Roundtable preceding the start of the Conference. The Fellows were introduced during the Conference's opening keynote session and the program gained visibility among nearly 3,000 conference attendees. The Program Director participated in a panel discussion at the conference to further promote the program. Over the course of the ensuing academic year, the National Hydropower Association, *Hydro Review* magazine, and multiple universities, recognized the work of HRF with the Hydro Fellowship Program.



Ilker Telci at his Poster Presentation at HydroVision.

Second Year of Program

During the second year in 2011, 14 Fellowships were awarded to students at 11 universities across the U.S. This round of Fellowships funded equal numbers of masters' and doctoral degree candidates. These Fellows conducted research in the following areas:

- Design Standardization for Integrating Micro Hydropower into Existing Infrastructure and Utility Systems
- A Methodology for Assessing the Value of Integrating Hydropower and Wind Generation
- Economic Feasibility of Pumped Storage Hydropower in Systems with Seasonally Low Flows
- Integrated Water and Energy Systems Analysis Tool Development
- Analysis of the Effects of Pre-Swirl on the Efficiency and Operating Range of Hydro Pumps used in Pumped Storage Facilities
- Climate Change Impacts on Columbia River Stream Flow and Hydropower Production
- Development of Low-Head Structures for the Purpose of Aeration
- Optimization of Reservoir Operations on the Rio Chama Using Multicriteria Decision Analysis and Multiobjective Operational Reservoir Modeling
- Predicting Fish Passage and Energetic Requirements for the Alaska Steppass Fishway Using a Computational Fluid Dynamics Model

- The Development of Clean, Surface-reconditioning Additives Based on Solid Inorganic Nanoparticles for Environment-Friendly Industrial Lubricating Compositions
- Coupling Hydropower and Intermittent Renewables Within the Grid
- Energy Production from Water Distribution Systems
- Erosion of Cohesive Sediment Due to Hydropower Releases
- Development of a Computational Tool for Predicting Water Quality in Large-Scale Flows

As in the first year, the program continued to be widely publicized including: the online DOE blog, the July 2011 issue of *Hydro Review* magazine (Conference Edition), professional organizations' newsletters, presentations at national conferences, the Midwest Hydro Users Group, the Northwest Hydropower Association and the National Hydropower Association. Congressman Joe Pitts (R-PA) recognized the Program and Fellow Keith Martin during his weekly radio show in August of 2011, and many of the Fellows received personal congratulatory letters from their Congressional delegations.



Students being recognized at plenary session of HydroVision.

The Fellows attended the HydroVision International 2011 Conference in Sacramento, California. Prior to the conference they participated in an educational session on hydropower production and marketing. During this session they participated in tours at Western Area Power Administration's Control Center and the Bureau of Reclamation's Folsom Dam. The tour and conference sessions offered the Fellows the opportunity to meet hydro professionals and exchange information on real world applications of their research work and their field of study. During the Fellows Roundtable held immediately preceding the start of the Conference, the Fellows presented their research topic updates and findings. The Fellows were again introduced to over 3,000 attendees of the HydroVision Conference at the opening session. Additionally the Grant Coordinator participated on a panel at HydroVision International 2011 to publicize the program.

A major program milestone occurred in 2011 when the first two Fellows graduated from their respective universities and were provided opportunities to connect with industry leaders for interview opportunities. The graduating Fellows presented their findings at the HydroVision International 2011 Conference and their work was web-published on the Foundation website and on the DOE Open EI online forum. All findings are listed in Appendix A.

Third Year of Program

The third year of HRF's Fellowship Program in 2012 built on successes from 2010-2011. The Foundation received applications from students at 19 universities and selected nine students from six universities. Two-thirds were Masters students and the other third were doctoral students.

The research included:

- A Methodology to Reduce the Strain on Hydro Turbines Using Life Extending Control of Multiple Energy Storage Systems
- Novel Materials and Coatings for Reduced Erosion and Cavitation Damage of Turbine Surfaces
- Real-time Condition Health Monitoring and its Application to Critical Hydropower Infrastructure
- Using Financial Risk Management Techniques to Enable More Sustainable Hydropower Production
- Stochastic Energy Scheduling
- Design of Hydropower Projects to Allow for the Downstream Passage of the American Eel
- Improving Representation of High-Elevation Snowpack for Summer Hydropower Forecasting
- Understanding Operational Flexibility in the Federal Columbia River Power System
- Design and Manufacturing Study of Hydraulic Turbine Systems Using Composite Materials with Natural and Recycled Fiber Reinforcements

All 31 students active in the program attended the Fellows Roundtable in Louisville, Kentucky. The Hydro Basics course was held at the U.S. Army, Corps of Engineers, Louisville District Office and topics included hydro basics and the environmental challenges of hydropower and opportunities. The students then were hosted by Louisville Gas & Electric to visit their Ohio Falls project. The week's events shed light onto industry needs, networking connections and job placement opportunities for

students. Fellows presented their research results and updates and introduced their topics at the Fellows Roundtable preceding the start of the conference. The Fellows were introduced again during the HydroVision 2012 conference's opening keynote session and



The 2012 class touring Ohio Falls in Louisville, KY.

the program gained visibility among nearly 3,000 conference attendees. In addition to the keynote introduction, students gave nine presentations throughout the week. The year



Andre Dozier with his award from HydroVision for Best Technical Paper of The Year.

was a tremendous success as students completed work, found jobs in industry and provided meaningful findings to advance hydropower knowledge.

One important achievement was that industry began to recognize the value and quality of the student research being supported by DOE and the Foundation. In 2012, Andre Dozier was recognized at HydroVision International with the 1st place Technical Paper of the Year for his software tool development for integrated water and power systems operation simulation and optimization. In this same year IEEE Power and Energy Society also honored this work with the Student Prize Paper Award. This was one of the first indicators that research being conducted by the Foundation's Fellows was relevant and impacting the industry.

Fourth Year of Program

In 2013, the final traditional selection occurred for the last class of students purely funded by Fellowship funds. The program received applications from 26 universities and 10 students from 9 universities were funded. Due to the shorter nature of funding from this group of students, post-masters researchers were invited to apply for funding and this group represented 70% of students funded, 20% were masters and 10% traditional doctoral students. This brought the total number of Fellowships funded to 43. The group attended the Fellows Roundtable hosted by Knight Piésold Consulting in Denver, Colorado, where they learned about hydro basics, policy and regulatory issues in the United States before they visited the Bureau of Reclamation's Mt. Elbert Pumping Plant. During the week in addition to the HydroVision 2013 keynote introduction by Program Director, Brenna Vaughn, there were a total of seven technical, poster and session presentations by the Foundation.



Program Director Brenna Vaughn speaking prior to keynote with Colorado Governor John Hickenlooper about the program.

The 2013 research topics included:

- Development and Demonstration of Value Analysis Methodology for Hydropower Flow Measurement Enhancement
- Simulation, Analysis, and Prevention of Vortex Rope Formation in Hydraulic Turbine Draft Tubes
- Hydroturbine Aeration Design Software for Mitigating Adverse Environmental Impacts and Increasing Hydropower Capacity
- Coordinated Predictive Control of a Hydropower Cascade
- Advanced Study of Wind Power Variability on the Federal Columbia River Power System
- Computation of Cavitating Flow in Hydroturbines
- Mitigating Hydropower Generators' Financial Risk from Climate Variability in Multi-Purpose Water Management Systems
- Cost-Effective Improvements to Surface Bypass Systems for Alosines
- Pump-Storage Hydropower Design and Implementation in an Urban Setting
- Improving on Hydropower Mitigation Success by Refining Predictions of Grain Motion

Fifth Year of Program

In July of 2014, the students attended HydroVision International in Nashville, Tennessee, where the U.S. Army, Corps of Engineers welcomed the group and provided the hydro basics course for new students as well as an introduction to the Low Impact Hydropower Institute by their Executive

Director. One new addition to the program in July was a meet-and-greet session with DOE staff and the national labs during the conference. Adam Witt found an opportunity to work with Oak Ridge National Laboratory, students were able to connect with the national laboratories to access information, and mentors, and DOE staff said that they received valuable insight to the caliber of the research and how it ties into the DOE strategy. This networking opportunity was so valuable that it was continued in 2015 in Portland, Oregon.



Minal Parekh participating in panel at HydroVision in 2014.

In 2014, the program transitioned into the closeout phase as final research findings were submitted by all 43 Fellows awarded under the Fellowship program. The HRF has worked diligently to continue the successes of this program through follow-on funding competitively awarded to HRF for the Research Awards Program (RAP). In 2014, the first round of students was selected into this new program. In 2015, another eleven students were selected by the foundation with funding from Fellowship program

supporting summer research activities, with the balance of their research to be supported through the RAP.

Their topics include:

- Optimization of Climbing Substrates for Upstream Eel Passage Structures
- Pump-Storage Hydropower Design in a Wastewater Treatment Facility with an Aerating Runner
- Evaluation of the Effectiveness and Long-Term Sustainability of Artificial Floods as a Sandbar Reconstruction and Maintenance Practice
- Detecting Internal Erosion in Earthen Dams
- Advanced Analysis of Hydroelectric Turbine Condition Monitoring Data for Early Damage Detection
- Application of Laser Based Additive Manufacturing to Innovate Novel Hard Surfaces and Repair Damaged Ones
- Hydrologic Regimes and Their Modifications: A Dynamic System Theory Approach and Implications for Hydropower Operations
- Maximizing the Habitat Restoration Potential of Controlled Releases at Hydropower Dams; Understanding Impacts of Hydrograph Form on Sediment Transport
- Public Acceptance of Hydropower Relicensing: Economic, Environmental, and Social Trade-offs
- A Hardware Testbed for Validation and Optimization of Variable Speed Hydropower Systems
- Controls on the Burial Efficiency of Reservoir Sediments: Understanding the Net Carbon Balance of Hydroelectric Reservoirs

These eleven students attended HydroVision International 2015 in Portland, OR alongside other Research Awards Program students and attended the hydro basics course hosted by the U.S. Army, Corps of Engineers which included presentations from manufacturers, DOE staff and a tour of the Corps' Bonneville Lock and Dam. These students' research results will be captured in the final technical findings report for the Research Awards Program.



*2014 Class at Old Hickory Plant
in Nashville, TN*

Partnership Program

A major step forward in the program is the formation of a partnership program. The HRF worked to inspire 3rd party support for the program in addition to the generous support provided by the host universities. It is important to note that the hydropower industry as a whole is fiscally very conservative, and takes a long-range view. HRF was successful in establishing six partnerships during the program. The HRF partnered with Avista Foundation, PennWell Corporation, US Bureau of Reclamation, Knight Piésold Consulting, Weir American Hydro and the U.S. Army, Corps of Engineers' Hydroelectric Design Center. The Foundation met its cost-share support over the life of the grant.

It is also important to note, that while not accounted for in this program, universities participating in the program contributed substantial in-kind support to the Fellows.

“The hydropower specific focus of the Foundation affords Knight Piésold the opportunities to immerse a graduate level individual in project design work under the guidance of licensed professional engineers. Knight Piésold understands the importance of a real world application to academic studies, and looks forward to providing and receiving the benefits of this outstanding mentoring opportunity.”

*-Sonya Reiser, Engineer,
Knight Piésold Consulting*

Challenges/Lessons learned

Under-estimating how efficiently the program would run

The biggest surprise was discovering that the program was running efficiently and that the program would be able to support more graduate level students than originally envisioned. DOE was integral in identifying pathways forward to maximize the impact of the program.

Understanding traditional university funding structures

Universities are accustomed to running grants through their Offices' of Sponsored Research which can have a attached a large overhead percentage, ranging from 20-60% of the award. The HRF had to work with students to pay them directly and work with the Office of Sponsored Research at each university to ensure that funding reached students and their tuition correctly. This was not an overwhelming process or issue, but was not anticipated in the original methodology. Over the course of the funding there were minor tweaks to application forms to glean better information and streamline the process, but the overall methodology was seamless and executed efficiently by the Foundation.

Partnerships

As the Foundation developed the partnership program, it was aggressive in thinking utilities and consulting firms would fund a whole Fellowship award for a student. The Foundation has had to reimagine this approach and find creative solutions including advertising different levels and means of support to create mechanisms for partners to

provide in-kind contributions, cash donations, travel support and internships. As partnerships were developed, the Foundation identified the need to recognize the contributions provided by the host universities. Each host university provides significant additional support of a graduate student's classroom work by providing office space, computing capabilities, labs and technology to support this work.

Program Facts

Number of Applications

Applications were received from 52 different universities in 26 states during four separate selection processes. Of those, 54 students were selected from 24 universities in 19 states. The Program truly designed and implemented a nation-wide approach reaching over half of the United States through contacting over 1,200 contacts. The HRF also reached out to colleges and universities, which historically enrolled a diverse student body. The Foundation utilized press releases to industry publications, web page advertisements, Facebook posts regarding funding opportunities, and email blasts to publicize the opportunity as widely as possible.

Of the 43 funded Fellows who completed their work by 2014, 41% were masters' students, 41% doctoral and 18% post-masters researchers.

Areas of Study

Topics covered a wide array of topics from a broad group of perspectives. While the Fellows, working with the advisors, were free to propose any topics via an "other" category, virtually all Fellows linked their research topics to one or more of the topics identified by the HRF.

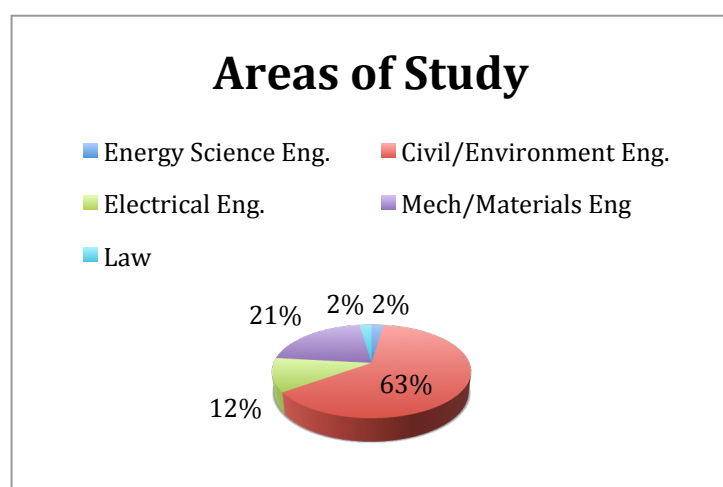


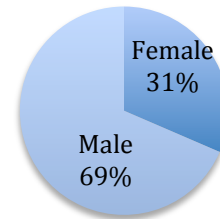
Table 1-Breakdown of areas of study

Number of Projects Funded	Percentage	Degree/Area of Study
1	2%	Energy Science Engineering
27	63%	Civil/Environmental Engineering
5	12%	Electrical Engineering
9	21%	Mechanical/Materials Engineering
1	2%	Law

Demographics of Fellows

According to the National Science Board's annual "Science and Engineering Indicators Report"¹ in 2014, women make up 28% of the STEM workforce. Of all 54 projects funded by HRF, 31% were research projects conducted by women. This indicates that awards were in line industry averages and applications were selected on merit rather than gender.

Male vs. Female



Funding Time and Industry Placement

The HRF examined which projects were most successful in terms of funding duration vis a vis the likelihood of a Fellow joining the hydropower industry. The Foundation found that of the 19 Fellows funded only one-year 66% joined industry and 70% completed the work on time and finished their degree under HRF funding. The 10 funded projects funded two-years joined industry 75% of the time but only half the time did they finish their work on time and complete degrees using the HRF funding. The four students funded three-years all joined industry and 75% completed the work on time and finished their degrees with the funding.

The analysis of this shows that there is not a strong correlation between funding duration and completing on time, but that there may be an argument that the longer students are funded to do hydropower research, the much more likely they are to join the hydropower industry.

Program Management

The Foundation worked over the funding period to manage the program budget in a manner that had low overhead and ran efficiently enough to make more awards than originally anticipated. The program staff was able to report out on money spent reconciled to the cent and maintained a clear budget tracking process.

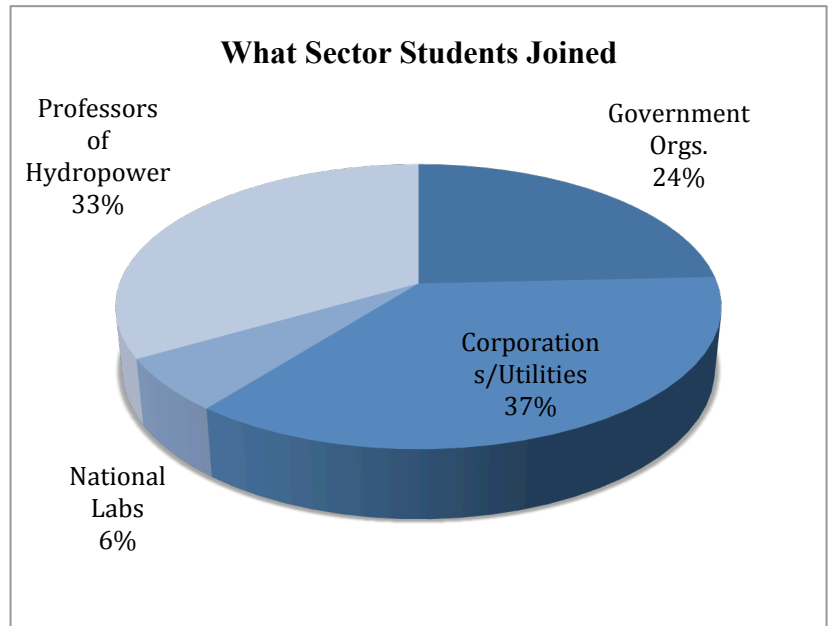
The program and Foundation received regular required audits and the auditors reported back with strong reports indicating clean audit results.

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¹ National Science Board. *Science and Engineering Indicators 2014*. Retrieved from: <http://www.nsf.gov/statistics/seind14/index.cfm/overview/c0i.htm>

Where did Fellows go to work?

One of the key metrics of success was to find out how many new scientists and engineers the Foundation could attract to hydropower through the use of a Fellowship, networking, educational and career placement opportunities. Following their Fellowship, 77% of students were placed in industry or continued valuable research at the universities or national labs. Of those joining the industry 12 joined corporations, 11 continued on in hydropower research and educating the next generation of leaders, 8 took government positions related to hydropower, and 2 joined national labs. Following is a list of Fellows and their initial placements in the hydropower industry following completion of their Fellowships:



1. Sean Brosig - U.S. Army, Corps of Engineers, Hydroelectric Design Center
2. Brian Campbell - Started Campbell Consulting to provide services for hydropower in irrigation systems
3. Mark Christian - Oak Ridge National Lab Post-Doc
4. Mitch Clement - Colorado Center for Advanced Decision Support for Water and Environmental Systems
5. Lisa Dilley - Knight Piésold Consulting
6. Andre Dozier - Professor teaching hydropower at Colorado State University
7. Hosein Foroutan - National Academy of Sciences continuing hydropower research
8. Benjamin Foster - Continuing on PhD at University of North Carolina furthering initial research
9. Michael George - Continued on to PhD related to rock scour on dams at UC, Berkeley
10. Mohammad Hajit - Continuing Hydropower Research at St. Anthony Falls Lab at the University of Minnesota
11. Andrew Hamann - Continuing on PhD related to hydropower
12. Jordan Kern - Post-Doc work at University of North Carolina in collaboration with Duke Energy
13. Marina Kopytikovisky - Tetra Tech
14. Kelcey Lajoie - Bonneville Power Administration
15. Ann Marie Larquier - USKH (Now Stantec)
16. Keith Martin - Peace Corps in Africa working on mechanical engineering for small hydro
17. Matthew McDonald - Civil EIT II at Stantec

18. Eliot Meyer - Post-Doc work at University of North Carolina in collaboration with Duke Energy
19. Ryan Morrison - U.S. Geological Survey- Fort Collins, CO
20. Kevin Mulligan - U.S. Fish and Wildlife Service-Fish Passage Engineering Team
21. Minal Parekh - U.S. Army, Corps of Engineers, Risk Management Center
22. John Petrie - Washington State University Civil Engineering Professor
23. Kathryn Plymesser - Professor at Montana State University teaching hydropower
24. Mark Raleigh - National Center for Atmospheric Research
25. Pavlo Rudenko - Founded Tribotex- A lubricant company for hydropower equipment. Received an SBIR grant to continue work
26. Chris Schleicher - Post-doc at Lehigh University continuing hydropower research
27. Heidi Smith Post - Doc at University of Idaho on sediment transport
28. Karen Studarus - Pacific Northwest National Lab
29. Sue Nee Tan - Pacific Gas and Electric and Advisory Board Member for HRF
30. Yushi Wang - CFD Modeler Stantec Engineering
31. Katherine Weidner - Black and Veatch
32. Marc Whitehead - HDR, Inc.
33. Adam Witt – Oak Ridge National Laboratory

There were ten students who pursued opportunities outside of hydro at organizations including Lyft, Terra Power, and ATA engineering.

Feedback on Program

From the hydropower industry:

“Looking back through our history reveals that for well over a century hydropower has been the backbone of America’s electricity portfolio. It powered the nation through the Great Depression and fueled our war effort during World War II. And today, hydropower continues its legacy as America’s original and largest renewable electricity resource. Hydropower’s future and potential growth is only as great as the individuals that continue to innovate. The Hydro Research Foundation has been at the forefront of finding, fostering and guiding a new generation of hydropower talent. After just five years, HRF has placed 75% of its students into jobs within the industry. Thanks to HRF, these young individuals will undoubtedly spur new technological development – from new turbine applications and designs to enhanced operational regimes. HRF’s is helping to ensure that millions of American’s will continue to have access to clean, affordable and reliable hydropower for another century.”

-Linda Church-Ciocci, Executive Director, National Hydropower Association

“The U.S. Army, Corps of Engineers is the largest single hydropower producer in the United States, producing nearly one fourth of the nations generated hydropower capacity. Our nation has a lot at stake in attracting, developing, and ultimately turning our brilliant engineers loose to address current and future challenges in the hydropower industry. The Corps Hydroelectric Design Center (HDC) has the vision to be "Leaders in Hydropower Engineering" and to do so we must utilize our most valuable resource - people - to the greatest extent. HDC is proud to partner with the Hydro Research Foundation to help educate and train top technical talent to be a part of the exciting hydropower field. Combining the Foundation's scholarship contributions along with the Corps hands-on industry opportunities creates a partnership that will likely be second-to-none in developing and preparing outstanding men and women capable of embracing the challenges in the hydropower industry for years to come.”

–John Etzel, Deputy Director of the Hydroelectric Design Center, U.S. Army, Corps of Engineers

“The hydropower specific focus of the Foundation affords Knight Piésold the opportunities to immerse a graduate level individual in project design work under the guidance of licensed professional engineers. Knight Piésold understands the importance of a real world application to academic studies, and looks forward to providing and receiving the benefits of this outstanding mentoring opportunity.”

–Sonya Reiser, Engineer, Knight Piésold Consulting

“I have recently had the privilege to work with Dr. Adam Witt and Oak Ridge National Laboratory on a project for the national utility in Thailand related to sustainable infrastructure for the Mekong River. Adam’s insight, judgment, technical knowledge, communication skills, and maturity make me very proud to have been a small part of the HRF Fellowship Program.”

–Patrick March, Hydro Performance Processes



*2013 Class at Mt. Elbert Pumping Plant
Leadville, CO*

From professors:

“We are used to traditional research appointments. The Fellowships or awards have been very seamless in the whole last year of their work with the HRF. One ended up at U.S. Army Corps of Engineers, Hydroelectric Design Center, and one at BPA. So we have been lucky in that. It has been easy to implement. We appreciate how this program is administered. It is well structured with latitude to execute project.”

-Dr. Ted Brekken, Oregon State University

“The HRF Fellowship meant that I could get back into hydropower research with a graduate student. I believe that the funds were well invested because my students performed research that is of interest to the hydropower industry. Receiving a Fellowship from a national organization is viewed positively by academic institutions.”

-Dr. John Gulliver, University of Minnesota

“Everything has been working really well. Two students involved from our program, and I think the funding and the HydroVision opportunity has been incredibly beneficial. Megan Kenworthy met with Idaho Power and others, which could lead to employment. I think it is a really wonderful program. I have enjoyed having my students participate.”

-Dr. Elowyn Yager, University of Idaho

Student feedback on impact of funding:

“I cannot thank HRF enough! The Fellowship made my research possible and gave me access to all kinds of experts in the hydro industry. My experience helped with the transition from academia to industry. I am loving my new job at Black & Veatch.”

-Katherine (Birckbichler) Weidner

“I really do appreciate the opportunity HRF gave me, I wouldn't be where I'm at now without it. So anything you all need just let me know.”

-Kevin Mulligan

“It was distinguished honor to receive a HRF Fellowship. The Fellowship not only provided generous financial support, but also opened many doors to develop contacts and future job opportunities in the hydro industry. It was also allowed me to meet and collaborate with other researchers at academic institutions across the country. The program provided excellent exposure for my research and myself and was absolutely instrumental in initiating my project at UC-Berkeley. The desire of the HRF to develop such a great environment for graduate research students speaks highly of the commitment and passion of those involved to the Hydro industry in which they work. For that I would like to say thank you to the Hydro Research Foundation.”

-Mike George

“My HRF Fellowship allowed me to extend previous research on hydropower and wind integration. It also paved the way for a full-time research position at the University of

Colorado Center for Advanced Decision Support for Water and Environmental Systems (CADSWES). The research carried out through my HRF Fellowship also opened the door for further research on hydropower and wind integration in a collaborative effort between CADSWES and the National Renewable Energy Laboratory. This research continues to demonstrate the important role hydropower plays in a green energy future.”

-Mitch Clement

“HRF provided me the insight, skills, and knowledge necessary to realize how my interests and background in geomorphology, flow regimes, and habitat can integrate with and inform hydropower projects. These are especially important topics in the energy future of Alaska!”

-Ann Marie Larquier

“HRF has been instrumental in granting me exceptional graduate studies that are highly applicable throughout the water and energy disciplines. Through the program, I have developed valuable relationships throughout academia and industry with engineers, managers, recruiters, and leaders of companies, government organizations, and nonprofits throughout the globe. I am very grateful to HRF and its Fellowship Program for connecting me with such great potential opportunities.”

-Andre Dozier

Quality & Value of Research

The research and the caliber of the new entrants to hydropower are high-value to the industry. Beginning in 2012, Fellows’ work has been recognized for its high caliber. Over the course of this program many high level technical awards were made to Fellows. Students received awards for the best technical paper, best poster presentation and people’s choice awards in conferences. Andre Dozier, Amelia Shaw, Adam Witt, Mark Christian and Karen Studarus were all award winners at HydroVision for their cutting edge research.

A notable award was in 2012; Andre Dozier received an award at HydroVision for the Best Technical Paper of the Conference. In this same year IEEE Power and Energy Society also honored this work with the Student Prize Paper Award.

To date, 40 Fellow’s research publications have been cited 220 times by subsequent researchers. This data was pulled from Google Scholar, which is an online tool for tracking citations and publications.

Fellows have received recognition through publishing their HRF-funded research results in 14 industry and peer-related journals.

Publicity

The publicity that the program and Fellows received at conferences speaks to the caliber of students that are being funded and reinforces that the brightest young researchers have been attracted to and supported by this program. Over the course of the funding 71 presentations were made regarding the research and program, 43 final findings were published, 33 additional publications were created. The presentations, publications and products can be found in Appendixes C, D, and E. Throughout the funding, there was a consistent stream of communication to the hydropower industry and universities creating a highly visible program.



The students chosen to be the first fellows under the Hydro Research Foundation's Fellowship Program, and foundation personnel, are (from left to right): John Petrie, Linda Church-Ciocci (executive director of HRF), Jordan Kern, Ann Marie Larquier, Michael George, Minal Parekh, Adam Witt, Marina Kopytkovskiy, Jonathan Lamonagne, Justin Hannon, Brenna Vaughn (grant administrator and event coordinator), and Deborah Linke (program director).

on Columbia River stream flow and hydropower production, with advisor Dr. Michael Barber;

— Garrett Monson, University of Minnesota, development of low-head structures for the purpose of aeration, with advisor Dr. John Gulliver;

— Ryan Morrison, University of New Mexico, optimization of reservoir operations on the Rio Chama using multicriteria decision analysis and multi-objective operational reservoir modeling, with advisor Dr. Mark Stone;

University, the development of clean, surface-reconditioning additives based on solid inorganic nanoparticles for environment-friendly industrial lubricating compositions, with advisor Dr. Amit Bandyopadhyay;

— Sue Nee Tan, Cornell University, coupling hydropower and intermittent renewables within the grid, with advisor Dr. Christine Shoemaker;

— Ilker Telci, Georgia Institute of Technology, renewable energy production from water distribution systems,

The boomer generation — the men and women who have operated the plants, maintained the equipment, designed the facilities, and constructed and refurbished the infrastructure — are nearing retirement age.

— Minal Parekh, Colorado School of Mines, evaluating internal erosion in earth dams using non-destructive methods, with advisor Mike Mooney;

— John Petrie, Virginia Tech University, modifying hydropower releases to reduce riverbank erosion, with advisor Panayiotis Diplas;

— Kathryn Plymness, Montana State University, predicting fish passage and energetic requirements for the Alaska Steppass fishway using a computational fluid dynamics model, with advisor Dr. Joel Cahoon;

— Pavlo Rudenko, Washington State

with advisor Dr. Mustafa Aral;

— Yushi Wang, University of Iowa, development of a computational tool for predicting water quality in large-scale flows, with advisor Dr. Marcela Politano;

— Katherine Weidner, Virginia Tech, erosion of cohesive sediment due to hydropower releases, with advisor Panayiotis Diplas; and

— Adam Witt, University of Minnesota, developing a technology which can predict gas transfer at low head and high head structures, with advisor Dr. John Gulliver.

The fellowship program has had a

significant positive impact on these students. Ann Marie Larquier, a master's student, says, "When I applied for the HRF fellowship, I had big ambitions for a career in water resources but wasn't sure how to best pursue them or in what sub-discipline to focus. This fellowship has exposed me to a breadth of opportunities and a well-rounded understanding of the hydropower industry. HRF's support has allowed me to conduct thorough, relevant and timely research on the topic of hydropower resources from glacial sources. I hope to apply my new knowledge to Alaska's long-term renewable energy future."

Minal Parekh, a doctoral student, notes, "The Hydro Research Foundation fellowship has given me a greater understanding of how my technical research fits into an overall energy solution. As I study earthen dams as aging infrastructure and investigate methods to detect early signs of failure, opportunities provided by the fellowship have provided me with insight into operations, performance and reliability of dams as a renewable power source. Through the foundation, I have met many people from within the industry with unbounded enthusiasm for hydropower and with equal willingness to share their knowledge and experience."

The Hydro Fellowship Program has scouts and coaches

The program established a steering group comprised of leaders from academia, industry, utilities and associations. These 12 men and women provide the overall guidance and frame of reference for the program. Part of their task is to keep a keen eye out for emerging issues in order to develop and fine-tune an annual list of research priorities.

Another significant activity is selection of the fellows. The foundation has designed and implemented a review and selection process that assures that the fellows selected are not only strong academically but also have leadership skills because HRF believes that many of today's fellows will become tomorrow's leaders.

Another innovation is the provision

HydroReview Article in July 2011 showcasing the program and students.

Networks or collaborations fostered

The program was unique and non-traditional in its approach to fostering networks and collaborations. Going into the award, HRF believed that the hydropower industry is a community—interdependent, relatively small, and willing to share information for the good of the practice—and that this would be appealing to the Fellows. This proved to be correct.

There were 54 specific individualized collaborations created for each university student and advisor. From the initial collaboration between Fellow and Advisor, the

collaborative environment was broadened as each student was paired with an industry mentor and steering group mentor, creating collaborative teams of at least four individuals with germane, relevant technical experience for each research project.

Surrounding each project was a network of hydropower industry experts ready to support the students, their research and their career opportunities. The HRF Board of Directors actively worked to place students in industry and connect students with opportunities.

The program network also included six partners including Avista Foundation, U.S. Bureau of Reclamation, Knight Piésold Consulting, U.S. Army Corps of Engineers Hydroelectric Design Center, PennWell Corporation and Weir American Hydro. These partners provided invaluable internships, help with coordinating events, complimentary booth space and support of the students living stipends, travel and conference registration.

The network also included two major trade associations, National Hydropower Association and Northwest Hydroelectric Association. These associations generously provided registration support, tables at their events to showcase work, invaluable airtime at conferences to showcase the program, complimentary meeting space and incredible publicity for the grant and Fellows

The outcomes of these networks were high visibility for the DOE Wind & Water Power Technologies Office. The program, with its highly leveraged funding with support from partners and universities, and a ready-made network for each student to find entry points to hydropower careers, highlighted the DOE's support at every opportunity. Subsequent researchers are using the research from the Fellows actively and this continues to provide visibility to DOE programs.

Technologies/Techniques Advancements

Technology was used to advance many of the projects. Fellows used a variety of software including Riverware, FLOW3D, MODSIM, MATLAB, and CFD modeling platforms. Three models were created from the grant. Andre Dozier created an integrated water and power modeling tool, Mark Christian created a two- and three-dimensional regression code for flow measurement accuracy assessments, and Samuel Dyas created a model for monitoring health condition of turbines. These tools are available publically on the HRF website. Katherine Plymesser and Tresha Melong also used physical models in their fish passage research.

Each research product sheds new light on technology and advancements. Other highlights from the work included Mitch Clement's design of a methodology to assess the value of integrated hydropower and wind generation and Mike George's advancements in understanding rock scour. Students like Garrett Monson, Mohammad Hajit and Adam Witt gave valuable insight to aeration and gas transfer and tools to study critical dissolved oxygen issues. Three students worked on advancing materials, coatings and composites

for hydropower.

At Cornell University, Jonathan Lamontagne proposed an algorithm for market modeling to improve optimization of operations. At the University of North Carolina students looked at the economics of hydropower through deregulation of electric markets and managing financial risks through insurance indexes. There were 43 advancements through this work.

All of the technology advancements were captured in the final findings and are accessible on Open EI as well as the Hydro Research Foundation's website <http://www.hydroFoundation.org/research-results-by-category.html>.

The screenshot shows the CodePlex project page for 'Integrated Water and Power Model'. The page has a navigation bar with links for HOME, SOURCE CODE, DOWNLOADS, DOCUMENTATION, DISCUSSIONS, ISSUES, PEOPLE, and LICENSE. Below the navigation bar, there is a section titled 'An Integrated Water and Power Modeling Package' with a description of the open-source optimization package. To the right, there is a sidebar with a search bar, a 'download' button, and a table of project details including CURRENT version (IWPM 8.3.2), DATE (Tue Apr 9, 2013 at 1:00 AM), STATUS (Beta), DOWNLOADS (39), and RATING (0 ratings). At the bottom, there is an 'ACTIVITY' section and a 'DOWNLOADS' section.

Andre Dozier's online tool for Integrated Water and Power Modeling.

Inventions/Patent Applications, Licensing Agreements

Pavlo Rudenko filed Patent Application (US/61654089) on December 5, 2013, for Nanostructures with Functionally Different Surfaces.

Other Products

All of the research findings are housed both at the Foundation's website, www.hydrofoundation.org as well as on Open EI http://en.openei.org/wiki/Main_Page. Due to the vast volume of research that was conducted under this award, the Foundation was not able to include all findings in this report, but have placed them in two public spaces for use by the industry and future researchers.

This collection includes extensive data, literature review, research findings, databases, limited software models, and does not involve any instruments or equipment.

Highlights of the Foundation's Fellowship Program



- The Program executed a national approach to funding by reaching out to more than 1,200 contacts and had 26 different states apply for funding through 52 universities.
- Collaborative process were established and executed using a team of 14 steering group members, 24 partner universities, 54 students, 37 academic advisors, 25 industry mentors, 7 Foundation consultants, and the board of directors. 148 people were directly involved in this program.
- The funding touched 22 congressional districts in 19 states.
- Ninety-one students and advisors received funding through this project.
- Students at 24 universities in 19 states received funding.
- The program supported 54 students - more than double the number of students originally envisioned. Between June 2015-September 2015, 11 students were supported under the Fellowship program and will continue their research under the Research Awards Program.
- The HRF has assured widespread publicity for the Program, nationally and internationally, emphasizing DOE's important role in supporting hydropower. In total the program and funding were promoted on 71 different occasions.
- Thirty-three publications other than research findings resulted from this program.
- Forty-three unique pieces of research were completed resulting in advancement of industry knowledge and understanding.
- The work funded by DOE has been cited 220 by other researchers to date.
- All students between 2010-2014 completed the agreed-upon research which developed innovative technology, advance environmental mitigation, provided models for industry, and addressed cost-effective solutions to hydropower's most pressing needs.

- The Foundation developed career opportunities and internships for Fellows resulting in the placement of 77% of students in industry or continued hydropower related research.
- Six industry partnerships were successfully formed.
- Each Fellow was provided an industry and Foundation mentor to assure a ready-made personal hydropower network.
- From this funding, 8 research centers of excellence at universities on specific fields of study were fostered in 7 states where multiple students in a university department were funded.

Findings of Program

The Hydro Fellowship Program was an experiment designed to discover whether the hydropower industry could find mechanisms to attract new entrants to hydropower and ultimately place them in industry through conducting relevant research to benefit the industry. The answer was overwhelmingly yes. With a placement rate of 77% of students combined with all 43 students submitting findings to advance the industries understanding of pressing research topics the grant funding accomplished the goals.

This historic grant has empowered and engaged industry members from 25 organizations by working with 91 students and advisors at 24 universities. Not only did the funding directly impact the 91 students/advisors and 25 organizations, but there are also now more professors teaching hydropower with the addition of 11 new professors, teaching assistants and graduate researchers continuing to stimulate academic interest in hydropower. Ten alumni are now at national labs or research institutes working to advance hydropower research beyond the funding of HRF, and the private sector gained 12 employees who are now hard at work. With the addition of 14 new members in academia, the industry is now supported by at least 48 advisors and new professors continuing to find solutions and teach hydropower in their classes. This means that the funding has spread to academia by spurring interest in cutting edge problems.

We have seen multiple cases where Fellows such as Minal Parekh, Sam Dyas, and Chris Schleicher have directly influenced students to apply for funding and now they have students being funded through HRF under the Research Awards Program. This directly implies that alumni are continuing to find value in this work and funding. One alumni, Sue Nee Tan, was elected to the Advisory Board of the Hydro Research Foundation and now is giving back to the industry that she now belongs to and cares about as a direct result of this work. Eight advisors had more than one student funded, which resulted in fostering a research center of excellence on specific hydropower-related topics in seven states. To see the research topics build upon each other speaks volumes to the potential of this work. By connecting more students to hydropower research, the impact of findings build on one other leads to more impacting research.

An example of building on topics to grow new research was an original internal erosion project started by Minal Parkeh who led and cemented a new geotechnical program at Colorado School of Mines. The project was then picked up by a student in the Research Awards Program, Joy Foley, who is now working on furthering understanding of the field with Minal as her advisor.

The multiplier effect has taken hold through these examples and demonstrates that the funding has reached many beneficiaries, and resulting in a dramatic influx of needed, useful research. In addition there were 220 citations of these Fellow's publications, demonstrating that the DOE investment is building the knowledge base and that this investment is highly valued and serving as building blocks for advancing hydropower knowledge.

Using the research topics of interest over the funding period, students were able to hone in on the most pressing needs of industry and design compelling proposals to address those needs in their applications. This research came full circle when, at HydroVision International on several occasions, students received awards for the best technical paper, best poster presentation and people's choice awards in conferences. Andre Dozier, Amelia Shaw, Adam Witt, Mark Christian and Karen Studarus were all award winners at HydroVision for their cutting edge research. This demonstrates that the work is relevant, addressing critical need and being recognized in industry as valuable work.

Based on this initial work, it is clear that the DOE grant funding achieved the goals and has the capacity to draw students and academia into the orbit of hydropower and increase the conversation about industry research and development needs. The HRF has fostered unique partnerships at the host universities and has continued to thrive with the support of the universities, advisors, and of most significantly, the Department of Energy. The Foundation has demonstrated industry support through establishing mentorships, having partnerships underwriting some costs and articulating the universities support through in-kind cost sharing.

As the program began in 2010, the hydropower industry was dubious whether this program could spur real research and new entrants. They were hesitant to commit resources as mentors, provide underwriting for the costs of the program, and unsure of the caliber of students or research. As the program started into the third and fourth years, mentors were overt in their desire to participate as mentors, Companies supported the work through underwriting the Foundation and lent far greater support than the initial years. The support continues to grow in 2015 as the Foundation pursues the Research Awards Program.



A prototype turbine originally envisioned by Fellow, Chris Schleicher, in production by Research Award Program recipient, Fred Carter.

Epilogue

The program's initial success sparked the addition of the competitively awarded Research Awards Program in 2014. This program built on the success of the Fellowship Program with the following changes in structure:

- The priority was to conduct research and an ancillary benefit was to have workforce entrants reflecting updated hydropower industry priorities.
- The funding for each student was re-evaluated resulting in a reduction of annual support to allow more students to be reached with same amount of funding.
- Using the lessons learned from the Fellowship Program, the HRF was able to recognize university support for the researchers and was able to provide cost sharing of nearly 50% with the generous support from various partners including universities, industry and trade associations to more accurately represent contributions into the program.
- As of publishing of this report, 23 students are being funded through the Research Awards Program, and working to continue the vibrant refocused program that was started under the Fellowship Program.

The Foundation has found that the reduced award is still attractive to students and advisors, but that in many cases the funding from the Foundation must be supplemented either by university support or by the student holding a research assistantship for reduced tuition. The Foundation has accommodated this need by having flexibility in how the smaller awards are split among tuition, insurance and stipends. It is difficult to determine whether other high-caliber students are not applying due to the reduced funding structure, but it doesn't appear to affect the highly qualified selected students that are accepted into the Research Awards Program.

Future Work & Recommendations

The future work recommended is to continue to nurture graduate level programs through the Research Awards Program. The HRF sees that, with a cost-share commitment of nearly 50% of DOE's investment, DOE receives a highly leveraged, effective, and visible program to stimulate meaningful research. It is clear that DOE's investment in the program provides outstanding new engineers and scientist as hydropower workforce entrants and meets the strategic goals of the Wind and Water Power Technologies Office. The HRF is unique in its ability to select cutting-edge research with minimal overhead. The program has compelling results, which continue to add value to the DOE programs. The HRF recommends continuing the reduced support of students, but for two-year research tenures and to continue the cost-share commitment of 40% of the program cost by partners of the program.

Summary

In summary, the Hydro Fellowship Program has worked well, as evidenced by the outcomes of achieving research outcomes and attracting high-quality new entrants to the industry. Industry and the universities both recognize the need for, and value of, research related to hydropower. The HRF has been building a bright future for the industry by bringing high quality research and top-notch employees to hydropower.

Supporting Documents, Appendix, and Information

Appendix A

Summary of Final Findings

Final Findings from Grant Funding:

All findings are currently available on the Hydro Research Foundation's website:

www.hydroFoundation.org as well as through DOE's Open EI platform:

http://en.openei.org/wiki/Main_Page

Name	University	Final Research Title	Open EI link
Brosig, Sean	Oregon State University	A Methodology to Reduce the Strain on Hydro Turbines Using Advanced Life Extending Control of Multiple Energy Storage Systems.	http://prod-http-80-800498448.us-east-1.elb.amazonaws.com/w/images/7/73/SeanBrosig_Thesis.pdf
Campbell, Brian	Colorado State University	Identification Of Spatial And Topographical Metrics For Micro Hydropower Applications In Irrigation Infrastructure	http://prod-http-80-800498448.us-east-1.elb.amazonaws.com/w/images/9/93/BrianCampbell_Thesis.pdf
Cecchini-Beaver, Mark	University of Idaho	Transboundary Columbia River Operational Alternative Analysis In A Collaborative Framework	http://prod-http-80-800498448.us-east-1.elb.amazonaws.com/w/images/9/93/MarkBeaver_Thesis.pdf
Christian, Mark	University of Tennessee	Development and Operation of the Flow Measurement Accuracy Assessment Tool	http://prod-http-80-800498448.us-east-1.elb.amazonaws.com/w/images/3/33/MarkChristian_Thesis.pdf

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Clement, Mitch	University of Colorado- Boulder	A Methodology for Assessing the Value of Integrating Hydropower and Wind Generation	http://prod-http-80-800498448.us-east-1.elb.amazonaws.com/w/images/5/54/MitchClement_Thesis.pdf
Dilley, Lisa	University of Washington	Economic Feasibility of Pumped Storage Hydropower	http://prod-http-80-800498448.us-east-1.elb.amazonaws.com/w/images/1/13/LisaMaeDilley_Thesis.pdf
Dittrick, Stanley	Washington State University	Iron Bulk Amorphous Alloy Coating For Reduced Wear Damage Of Turbine Surfaces	http://prod-http-80-800498448.us-east-1.elb.amazonaws.com/w/images/5/5f/StanDittrick_Thesis.pdf
Dozier, Andre	Colorado State University	Integrated Water And Power Modeling Framework For Renewable Energy Integration	http://prod-http-80-800498448.us-east-1.elb.amazonaws.com/w/images/b/b3/AndreDozier_Thesis.pdf
Dyas, Sam	Colorado School of Mines	Condition Health Monitoring And Its Application To Cavitation Detection/Characterization Within Hydropower Turbines	http://prod-http-80-800498448.us-east-1.elb.amazonaws.com/w/images/d/d7/SamDyas_Thesis.pdf
Foroutan, Hosein	Penn State	Simulation, Analysis, and Mitigation of Vortex Rope Formation in the Draft Tube of Hydraulic Turbines	http://prod-http-80-800498448.us-east-1.elb.amazonaws.com/w/images/e/e4/HoseinForoutan_Thesis.pdf
Foster, Ben	University of North Carolina-Chapel Hill	Managing Water Supply Related Financial Risk In Hydropower Production With Index-Based Financial	http://prod-http-80-800498448.us-east-1.elb.amazonaws.com/w/images/b/b5/BenjaminFoster_Thesis.pdf

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		Instruments	
George, Michael	University of California-Berkeley	Block Theory Application to Scour Assessment of Unlined Rock Spillways	http://prod-http-80-800498448.us-east-1.elb.amazonaws.com/w/images/2/26/MichaelGeorge_Thesis.pdf
Greenhall, Adam	University of Washington	Wind Scenarios for Stochastic Energy Scheduling	http://prod-http-80-800498448.us-east-1.elb.amazonaws.com/w/images/d/d1/DamGreenhall_Thesis.pdf
Haji Mohammadi Sani Abadi, Mohammad	University of Minnesota	Euler-Euler Large Eddy Simulation Of Two-Phase Dilute Bubbly Flows With Mass Transfer Across Phases	http://prod-http-80-800498448.us-east-1.elb.amazonaws.com/w/images/e/ed/MohammadHaji_Thesis.pdf
Hamann, Andrew	Carnegie Mellon University	Coordinated Predictive Control of a Hydropower Cascade	http://prod-http-80-800498448.us-east-1.elb.amazonaws.com/w/images/5/53/AndrewHamann_Thesis.pdf
Hannon, Justin	University of Iowa	Image Based Computational Fluid Dynamics Modeling To Simulate Fluid Flow Around A Moving Fish	http://prod-http-80-800498448.us-east-1.elb.amazonaws.com/w/images/2/29/JustinHannon_Thesis.pdf
Kern, Jordan	University of North Carolina-Chapel Hill	Dynamic hydrologic-economic modeling of tradeoffs in hydroelectric systems	http://prod-http-80-800498448.us-east-1.elb.amazonaws.com/w/images/e/e1/JordanKern_Thesis.pdf
Kopytkovskiy, Marina	Colorado School of Mines	A Study Of Climate Change Impacts Of The Upper Colorado River Basin On Water Resources and Hydropower Production	http://prod-http-80-800498448.us-east-1.elb.amazonaws.com/w/images/c/c4/MarinaKopytkovskiy_Thesis.pdf
Lajoie, Kelcey	Oregon State University	An Advanced Study of Wind Power	http://prod-http-80-800498448.us-east-1.elb.amazonaws.com/w/images/2/26/KelceyLajoie_Thesis.pdf

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		Variability on the Federal Columbia River Power System	1.elb.amazonaws.com/w/images/7/76/KelceyLajoie_Thesis.pdf
Lamontagne, Jon	Cornell University	Real-Time Forecasting and Hydropower Reservoir Optimization	http://prod-http-80-800498448.us-east-1.elb.amazonaws.com/w/images/b/b8/JonLamontagne_Thesis.pdf
Larquier, Ann Marie	Alaska Pacific University	Differing Contributions Of Heavily And Moderately Glaciated Basins To Water Resources Of The Eklutna Basin, Alaska	http://prod-http-80-800498448.us-east-1.elb.amazonaws.com/w/images/1/1d/AnnMarieLarquier_Thesis.pdf
Leonard, Daniel	Penn State	Computation And Analysis Of Cavitating Flow In Francis-Class Hydraulic Turbines	http://prod-http-80-800498448.us-east-1.elb.amazonaws.com/w/images/9/9d/DanielLeonard_Thesis.pdf
Martin, Keith	Pennsylvania State University	Analysis of the Effects of Pre-whirl on the Efficiency and Operating Range of Hydro Pumps used in Pumped Storage Facilities	http://prod-http-80-800498448.us-east-1.elb.amazonaws.com/w/images/8/8f/KeithMartin_Thesis.pdf
McDonald, Matt	Washington State University	Climate Change Impacts On Reservoir Operations In The Columbia River Basin	http://prod-http-80-800498448.us-east-1.elb.amazonaws.com/w/images/9/91/MatthewMcDonald_Thesis.pdf
Melong (Price), Tresha	Worcester Polytechnic Institute	Evaluation of Bar Rack Designs to Allow for the Downstream Passage of Silver American Eels at Hydropower Facilities	http://prod-http-80-800498448.us-east-1.elb.amazonaws.com/w/images/f/f4/TreshaMelong_Thesis.pdf - Colorado Center for Advanced Decision Support

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			for Water and Environmental Systems
Meyer, Eliot	University of North Carolina	Financial Risk From Changing Lake Levels For Hydropower Producers On The Great Lakes	http://prod-http-80-800498448.us-east-1.elb.amazonaws.com/w/images/4/4b/EliotMeyer_Thesis.pdf
Monson, Garrett	University of Minnesota	Study of Mass Transfer across Hydrofoils for Use in Aerating Turbines	http://prod-http-80-800498448.us-east-1.elb.amazonaws.com/w/images/a/a0/GarrettMonson_Thesis.pdf
Morrison, Ryan	University of New Mexico	Managing Complex Water Resource Systems for Ecological Integrity: Evaluating Tradeoffs and Uncertainty	http://prod-http-80-800498448.us-east-1.elb.amazonaws.com/w/images/d/dc/RyanMorrison_Thesis.pdf
Mulligan, Kevin	University of Massachusetts-Amherst	An Analysis of Partial-Depth, Floating, Impermeable Guidance Structures for Downstream Fish Passage at Hydroelectric Facilities	http://prod-http-80-800498448.us-east-1.elb.amazonaws.com/w/images/9/94/KevinMulligan_Thesis.pdf
Parekh, Minal	Colorado School of Mines	Internal Erosion Monitored by Spatial-Temporal Pore Pressure Changes During Full-Scale Field Experiments	http://prod-http-80-800498448.us-east-1.elb.amazonaws.com/w/images/f/f7/MinalParekh_Thesis.pdf
Petrie, John	Virginia Tech	Combining fixed- and moving-vessel acoustic Doppler current profiler measurements for improved characterization of the mean flow in a	http://prod-http-80-800498448.us-east-1.elb.amazonaws.com/w/images/4/4a/PetrieJohn_Thesis.pdf

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		natural river	
Plymesser, Kathryn	Montana State University	Modeling Fish Passage And Energy Expenditure For American Shad In A Steeppass Fishway Using a Computational Fluid Dynamics Model	http://prod-http-80-800498448.us-east-1.elb.amazonaws.com/w/images/f/f9/KathrynPlymesser_Thesis.pdf
Raleigh, Mark	University of Washington	Quantification of uncertainties in snow accumulation, snowmelt, and snow disappearance dates	http://prod-http-80-800498448.us-east-1.elb.amazonaws.com/w/images/1/10/MarkRaleigh_Thesis.pdf
Rudenko, Pavlo	Washington State University	Surface-Reconditioning Additives Based on Solid Inorganic Nanoparticles for Environment-Friendly Industrial Lubricating Compositions	http://prod-http-80-800498448.us-east-1.elb.amazonaws.com/w/images/1/13/PavloRudenko_Thesis.pdf
Schleicher, Chris	Lehigh University	Hydraulic Design and Optimization of a Modular Pump-turbine Runner	http://prod-http-80-800498448.us-east-1.elb.amazonaws.com/w/images/7/73/ChrisSchleicher_Thesis.pdf
Smith, Heidi	University of Idaho	Improving on Hydropower Mitigation Success by Refining Predictions of Grain Motion	http://prod-http-80-800498448.us-east-1.elb.amazonaws.com/w/images/c/c3/HeidiSmith_Thesis.pdf
Studarus, Karen	University of Washington	Understanding Operational Flexibility in the Federal Columbia River Power System	http://prod-http-80-800498448.us-east-1.elb.amazonaws.com/w/images/e/e8/KarenStudarus_Thesis.pdf
Tan, Sue Nee	Cornell University	A Stochastic Dynamic Programming Approach to	http://prod-http-80-800498448.us-east-1.elb.amazonaws.com/w/images/3/37/Sue

Building a Bright Future
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		Balancing Wind Intermittency with Hydropower	eNeeTan_Thesis.pdf
Telci, Ilker	Georgia Institute of Technology	Optimal Water Quality Management In Surface Water Systems And Energy Recovery In Water Distribution Networks	http://prod-http-80-800498448.us-east-1.elb.amazonaws.com/w/images/a/a1/IlkerTelci_Thesis.pdf
Wang, Yushi	University of Iowa	Development Of A Numerical Tool To Predict Hydrodynamics, Temperature And TDG In Hydropower Flows	http://prod-http-80-800498448.us-east-1.elb.amazonaws.com/w/images/b/b6/YushiWang_Thesis.pdf
Weidner (Birchbickler), Katherine	Virginia Tech	Evaluation of the Jet Test Method for determining the erosional properties of Cohesive Soils; A Numerical Approach	http://prod-http-80-800498448.us-east-1.elb.amazonaws.com/w/images/2/21/KatherineWeidner_Thesis.pdf
Whitehead, Marc	Oregon State University	Design and Manufacturing Study of Hydroelectric Turbines Using Recycled and Natural Fiber Composites	http://prod-http-80-800498448.us-east-1.elb.amazonaws.com/w/images/3/39/MarcWhitehead_Thesis.pdf
Witt, Adam	University of Minnesota	Analytical And Numerical Investigation Of An Air Entraining Hydraulic Jump	http://prod-http-80-800498448.us-east-1.elb.amazonaws.com/w/images/2/2c/AdamWitt_Thesis.pdf

1 Appendix B

Students Funded

Name	Year Selected	Graduate Level	University
Beaver, Mark	2012	Masters	University of Idaho
Birckbichler (Weidner), Katherine	2011	Masters	Virginia Tech
Brosig, Sean	2012	Masters	Oregon State University
Campbell, Brian	2011	Masters	Colorado State University
Christian, Mark	2013	Post Masters Researcher	University of Tennessee
Clement, Mitch	2011	Masters	University of Colorado- Boulder
Dilley, Lisa	2011	Doctoral	Washington State University
Dittrick, Stanley	2012	Doctoral	Washington State University
Dozier, Andre	2011	Masters	Colorado State University
Dyas, Sam	2012	Masters	Colorado School of Mines
Foroutan, Hosein	2013	Post Masters Researcher	Penn State
Foster, Ben	2012	Masters	University of North Carolina-Chapel Hill
George, Michael	2010	Doctoral	University of California-Berkeley
Greenhall, Adam	2012	Doctoral	University of Washington
Hajit, Mohammad	2013	Post Masters Researcher	University of Minnesota
Hamann, Andrew	2013	Masters	Carnegie Mellon University
Hannon, Justin	2010	Masters	University of Iowa
Kern, Jordan	2010	Doctoral	University of North Carolina-Chapel Hill
Kopytkovskiy, Marina	2010	Masters	Colorado School of Mines
Lajoie, Kelcey	2013	Masters	Oregon State

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			University
Lamontagne, Jon	2010	Doctoral	Cornell University
Larquier, Ann Marie	2010	Masters	Alaska Pacific University
Leonard, Daniel	2013	Doctoral	Penn State
Martin, Keith	2011	Masters	Pennsylvania State University
McDonald, Matt	2011	Masters	Washington State University
Melong (Price), Tresha	2012	Masters	Worcester Polytechnic Institute
Meyer, Eliot	2013	Post Masters Researcher	University of North Carolina
Monson, Garrett	2011	Masters	University of Minnesota
Morrison, Ryan	2011	Doctoral	University of New Mexico
Mulligan, Kevin	2013	Post Masters Researcher	University of Massachusetts-Amherst
Parekh, Minal	2010	Doctoral	Colorado School of Mines
Petrie, John	2010	Doctoral	Virginia Tech
Plymesser, Kathryn	2011	Doctoral	Montana State University
Raleigh, Mark	2012	Doctoral	University of Washington
Rudenko, Pavlo	2011	Doctoral	Washington State University
Schleicher, William	2013	Post Masters Researcher	Lehigh University
Smith, Heidi	2013	Post Masters Researcher	University of Idaho
Studarus, Karen	2012	Doctoral	University of Washington
Tan, Sue Nee	2011	Doctoral	Cornell University
Telci, Ilker	2011	Doctoral	Georgia Institute of Technology
Wang, Yushi	2011	Doctoral	University of Iowa
Whitehead, Marc	2012	Masters	Oregon State University
Witt, Adam	2010	Doctoral	University of Minnesota

2 Appendix B

Workforce Placement List of Student Outcomes

Following their Fellowship 77% of students were placed in industry or continued valuable research at the universities or national labs. Here is where the students transitioned to following funding:

1. Sean Brosig - U.S. Army, Corps of Engineers, Hydroelectric Design Center
2. Brian Campbell - Started Campbell Consulting to provide services for hydropower in irrigation systems
3. Mark Christian - Oak Ridge National Lab Post-Doc
4. Mitch Clement - Colorado Center for Advanced Decision Support for Water and Environmental Systems
5. Lisa Dilley - Knight Piésold Consulting
6. Andre Dozier - Professor teaching hydropower at Colorado State University
7. Hosein Foroutan - National Academy of Sciences continuing hydropower research
8. Benjamin Foster - Continuing on PhD at University of North Carolina furthering initial research
9. Michael George - Continued on to PhD related to rock scour on dams at UC, Berkeley
10. Mohammad Hajit - Continuing Hydropower Research at St. Anthony Falls Lab at the University of Minnesota
11. Andrew Hamann - Continuing on PhD related to hydropower
12. Jordan Kern - Post-Doc work at University of North Carolina in collaboration with Duke Energy
13. Marina Kopytikovisky - Tetra Tech
14. Kelcey Lajoie - Bonneville Power Administration
15. Anne Marie Larquier - USKH (now Stantec)
16. Keith Martin - Peace Corps in Africa working on mechanical engineering for small hydro
17. Matthew McDonald - Civil EIT II at Stantec
18. Eliot Meyer - Post-Doc work at University of North Carolina in collaboration with Duke Energy
19. Ryan Morrison - U.S. Geological Survey- Fort Collins, CO
20. Kevin Mulligan - U.S. Fish and Wildlife Service-Fish Passage Engineering Team
21. Minal Parekh - U.S. Army, Corps of Engineers, Risk Management Center
22. John Petrie - Washington State University Civil Engineering Professor
23. Kathryn Plymesser - Professor at Montana State University teaching hydropower
24. Mark Raleigh - National Center for Atmospheric Research
25. Pavlo Rudenko - Founded Tribotex- A lubricant company for hydropower equipment. Received an SBIR grant to continue work
26. Chris Schleicher - Post-doc at Lehigh University continuing hydropower research
27. Heidi Smith Post - Doc at University of Idaho on sediment transport
28. Karen Studarus - Pacific Northwest National Lab
29. Sue Nee Tan - Pacific Gas and Electric and Advisory Board Member for HRF

- 30. Yushi Wang - CFD Modeler Stantec Engineering
- 31. Katherine Weidner - Black and Veatch
- 32. Marc Whitehead - HDR, Inc.
- 33. Adam Witt - Oak Ridge National Lab

1 Appendix C

Partner Organizations

Partner Organizations and mentor organizations:

The Foundation placed three students in internships. All Fellows had a mentor from industry. The Program has created mentorships and partnerships with 25 different organizations including:

- Alaska Energy Authority
- Alden Laboratory
- Alstom
- U.S. Army Corps of Engineers
- Avista Foundation and Avista Corporation
- Bonneville Power Administration
- U.S. Bureau of Reclamation
- Duke Energy
- Flow Science
- Golder and Associates
- Grant County PUD
- Hatch
- HDR, Inc.
- Hydrologics
- Idaho Power
- Knight Piésold Consulting
- Low Impact Hydropower Institute
- Pacific Northwest National Lab
- Portland General Electric
- PennWell Corporation
- Oak Ridge National Laboratory
- S. Scott and Associates
- San Francisco Water
- Sandia National Laboratory
- Voith Hydro
- Weir American Hydro

2 Appendix C

University Partners

Host Universities of Fellows:

- Alaska Pacific University
- Carnegie Mellon University
- Colorado School of Mines
- Colorado State University
- Cornell University
- Georgia Institute of Technology
- Lehigh University
- Montana State University
- Northern Arizona University
- Oregon State University
- Pennsylvania State University
- University of California-Berkeley
- University of Colorado- Boulder
- University of Idaho
- University of Iowa
- University of Massachusetts-Amherst
- University of Minnesota
- University of New Mexico
- University of North Carolina-Chapel Hill
- University of Tennessee
- University of Washington
- Virginia Tech
- Washington State University
- Worcester Polytechnic Institute

Appendix D

Program Presentations

Presentations from program:

- Minal Parekh, Poster presentation at ASDSO Dam Safety Summer, 2010.
- Presentation at Geological Society of American 2010 Annual Meeting, Denver Colorado at session titled Land use and Climate Change on Water Resources Sustainability. “Glacial Influences on Water Resources of the Eklutna Basin.” Ann Marie Larquier, Alaska Pacific University, October 31, 2010.
- Presentation to Dominion Energy and United States Army Corps of Engineers. “Final Report: Effects of With-ay and Within-Week Peaking on Bank Erosion at the Roanoke River Downstream of the Roanoke Rapids Dam. John Petrie, Soonkie Nam, Panayiotis Diplas & Marte S. Gutierrez, Virginia Tech University, February 17, 2011.
- Presentation at Northwest Hydropower Association annual meeting on panel entitled: Who Will Keep this Place Running? Attracting the Next Generation of Employees. “Hydro Fellowship Program.” Deborah M. Linke, Hydro Research Foundation, Portland, Oregon, February 22, 2011.
- Presentation at National Hydropower Association annual meeting plenary session. “Hydro Fellowship Program.” Deborah M. Linke, Hydro Research Foundation, Washington DC, April 4, 2011.
- Presentation at National Hydropower Association annual meeting on panel entitled: \$200 Million and County: Progress Report on DOE’s Waterpower Program. “Hydro Fellowship Program.” Deborah M. Linke, Hydro Research Foundation, Washington DC, April 5, 2011.
- Presentation to National Conference on Engineering and Ecohydrology for Fish Passage, Session A2, Engineering and Water Resources Track, Technical Fishways. “Simple Drag Force and Energy Calculations for Fish Passage Through a Model A Steeppass.” Katey Plymesser, PE and Brent Towler, PhD, PE, at University of Massachusetts, Amherst. June 27, 2011.
- Presentation at Midwest Hydro Users Group meeting entitled: “The Hydro Fellowship Program.” Deborah M. Linke, Hydro Research Foundation, Minneapolis, Minnesota, May 16, 2011.
- Presentation at Southwest Regional Meeting of the National Hydropower Association, entitled: “The Hydro Fellowship Program.” Deborah M. Linke, Hydro Research Foundation, Denver, Colorado, June 2011.
- Department Presentation entitled: “Tik Tock Talc Talk.” Pavlov Rudenko, Washington State University. Spring, 2011.
- Presentations to faculty of Alaska Pacific University and to the Hydro Fellows Roundtable, Hydro Research Foundation, “Differing Contributions of Heavily and

Moderately Glaciated Basis to Water Resources of the Eklutna Basin, Alaska.” Ann Marie Larquier, Alaska Pacific University, July 2011.

- Presentation on Hydro Fellowship Program at Plenary Session of HydroVision 2011, Sacramento, CA. Deborah Linke, Program Director, July 19, 2011.
- Presentations to third semi-annual PSU/WAH/DOE Hydropower Project Progress Report Meeting. “Effects of Pre-Swirl on Pump-Turbine Efficiency and Operating Range.” Keith Martin, Pennsylvania State University, December 13, 2011. First slide attached.
- Presentations to third semi-annual PSU/WAH/DOE Hydropower Project Progress Report Meeting. “Effects of Pre-Swirl on Pump-Turbine Efficiency and Operating Range.” Keith Martin, Pennsylvania State University, December 13, 2011.
- Presentation on Fellowship Program. Federal Inland Hydropower Working Group Telephone Meeting. Deborah Linke, Program Director, and Brenna Vaughn, Grant Coordinator, Hydro Research Foundation, January 30, 2012.
- Bonneville Power Administration, Reservoir System Modeling Technologies Conference. “Planned Improvements to MODSIM: Integrating River Basin Operations Modeling with Power System Economic Dispatch.” Andre Dozier, John Labadie and Dan Zimmerle. Colorado State University, February 21, 2012.
- Kathryn Plymessenger. Presentation at the Region 5 Science Seminar Series, US Fish and Wildlife Service. March 2012. Live broadcast can be accessed here: http://www.livestream.com/r5broadcasts/video?clipId=pla_9d8c114b-f57f-4494-9370-a051a1fala40&utm_source=lslibrary&utm_medium=ui-thumb
- Pavlo Rudenko, Presentations at Washington State University Materials Science and Engineering Program. March 8 & 9, 2012
- Pavlo Rudenko, Washington State University. Organized Invention2Venture Seminar at the University.
- Presentation on Fellowship Program. National Hydropower Association President’s Luncheon Annual Meeting Deborah Linke, Program Director, Hydro Research Foundation, April 17, 2012.
- Mark F. Cecchini-Beaver, University of Idaho. “Interpreting the Columbia River Treaty’s ‘Called Upon’ Flood Control Provisions in Light of Customary International Law.” Spring 2012-International Environmental Law.
- Mitch Clement. “Assessing the Value of Integrated Hydropower and Wind Generation.” University of Colorado, Center for Advanced Decision Support for Water & Environmental Systems Hydrology & Water Resources Seminar. May 2, 2012.
- Mitch Clement. “Assessing the Value of Integrated Hydropower and Wind Generation.” National Renewable Energy Laboratory. June 4, 2012.
- Andre Dozier, John Labadie & Dan Zimmerle. “Modeling Hydropower Units and Attaining Hydropower Targets Within MODSIM.” Documentation of Screenshots of Model. Undated.
- John Petrie, Panayiotis Diplas, Marte Gutierrez, & Soonkie Nam. “Determining the Primary Flow Direction in a Natural River with an Acoustic Doppler Current Profiler.” Third International Symposium on Shallow Flows. University of Iowa. June 6, 2012.

- Kathryn Plymesser. “Design for the Passage of River Herring in the Northeast.” University of Massachusetts. National Conference on Engineering and Ecohydrology for Fish Passage, June 2012.
- Adam Witt & John Gulliver. “Modeling Oxygen Transfer Efficiency at Low-Head Gated Dams.” International Junior Researchers and Engineers Workshop on Hydraulic Structures. Logan, Utah. June 17-20, 2012.
- Presentation on Fellowship Program. HydroVision International Conference Opening Keynote Marla Barnes, Publisher, PennWell Corporation. July 17, 2012. Script attached.
- Presentation of Fellowship Program. National Hydropower Association Research and Development Committee Meeting Deborah Linke, Program Director, Hydro Research Foundation. July 16, 2012.
- Presentation of Fellowship Program. National Hydropower Association Hydraulic Power Committee Meeting Deborah Linke, Program Director, Hydro Research Foundation. July 16, 2012.
- John Petrie. “Numerical Simulation of Jet Test and Associate Soil Erosion.” Virginia Tech, International Conference on Scour and Erosion. August 2012.
- John Petrie. “Site assessment for hydrokinetic projects in rivers and tidal channels.” HydroVision International. July 19, 2012.
- Andre Dozier. “Software tool development for integrated water and power systems operations simulation and optimization.” HydroVision International. July 19, 2012.
- Adam Witt and John Gulliver. Poster presentation. “Predicting oxygen transfer at low-head dams.” HydroVision International. July 19, 2012.
- Ilker Telci. Poster presentation. “Renewable energy production from water distribution systems.” HydroVision International. July 19, 2012.
- Pavlo Rudenko, Phil Meier, and Christ Konstantellos. Poster presentation. “Surface-reconditioning additives based on solid inorganic nanoparticles from environment-friendly industrial lubricating compositions.” HydroVision International. July 19, 2012.
- Minal Parekh. “Hydropower’s aging work force and the transition to a new generation of workers.” HydroVision International, July 19, 2012.
- Lisa Dilley, Matt McDonald and Michael Barber. “Integration Challenges and Opportunities Associated with Hydropower and Renewable Energy in the Pacific Northwest”. Universities Council on Water Resources. July 17, 2012.
- Matthew McDonald and Michael Barber. “Expectations for Tributary Headwaters Management: Libby Dam Operations in a Changing Climate”. American Water Resources Association, Washington Association. September 12, 2012.
- Mark Cecchini-Beaver. “Columbia River Operational Alternative Analysis in a Participatory Framework.” 4th Annual Symposium on Columbia River Governance. October 12, 2012.
- Karen Studarus. “Measuring Operational Flexibility in the Federal Columbia River Power System.” University of Washington Seminar. December 6, 2012.

- Ilker Telci. “Optimal Water Quality Management in Surface Water Systems and Energy Recovery in Water Distribution Networks.” Georgia Technical Institute. December, 2012.
- Andre Dozier. “Integrated Water and Power Modeling Framework for Renewable Energy Integration.” Colorado State University. October, 2012.
- Brian Campbell. “Identification of Spatial and Topographical Metrics for Micro Hydropower Applications in Irrigation Infrastructure.” December, 2012.
- Marina Kopytkovskiy. “A Study of Climate Change Impacts of the Upper Colorado River Basin on Water Resources and Hydropower Production.” November, 2012.
- Mark Cecchini-Beaver. “Columbia River Operational Alternative Analysis in a Participatory Framework.” Water Resources Department Meeting for the University of Idaho. Boise, ID. February 14, 2013.
- Benjamin Foster. “Using Financial Risk Management Contracts to Reduce Water Scarcity Risk in Hydropower Production.” Water Resources Research Institute Conference. Raleigh, NC. March 21, 2013.
- Jordan Kern and Gregory Characklis. “Wind Energy as a Driver of Environmental Flows Downstream of Hydroelectric Dams.” Water Resources Research Institute Conference. Raleigh, NC. March 21, 2013.
- Jordan Kern and Gregory Characklis. “Wind Energy as a Driver of Environmental Flows Downstream of Hydroelectric Dams.” American Geophysical Union Annual Meeting. San Francisco, CA. December, 2012.
- Jordan Kern . “Wind Energy as a Driver of Environmental Flows Downstream of Hydroelectric Dams.” In-House Seminar Series. University of North Carolina at Chapel Hill. January, 2013.
- Karen Studarus. “Annual Poster Contest University of Washington. February, 2013.
- Benjamin Foster. “Using Financial Risk Management Contracts to Reduce Water Scarcity Risk in Hydropower Production.” Property and Environment Research Center Bozeman, Montana. June 28, 2013.
- Tresha Melong. “Hydro Research Foundation.” National Hydropower Association Annual Conference. April 23, 2013.
- Kathryn Plymesser. “Modeling Passage for American Shad in a Steeppass Fishway using a CFD Model.” International Conference on Engineering and Ecohydrology for Fish Passage at Oregon State University in Corvallis, OR. June 25, 2013.
- Pavlo Rudenko. “Surface Tribofilms Generated by Magnesium Hydrosilicates in Oils.” Society of Tribologists and Lubrication Engineers Annual Meeting. Detroit, Michigan. May 6, 2013.
- Sue Nee Tan. “A Stochastic Dynamic Programming Approach to Balancing Wind Intermittency with Hydropower.” Environmental and Water Resources Institute Congress. Cincinnati, Ohio. May 21, 2013.
- Matthew McDonald. “Small Scale Energy Storage.” Energy and Sustainability 2013 Conference. Bucharest, Romania. June 20, 2013.

- Deborah Linke. Presentation at National Hydropower Association President's Luncheon. April 22, 2013.
- Deborah Linke & Brenna Vaughn. "Workforce Development" presentation, CEO Council, National Hydropower Association. April 25, 2013
- Karen Studarus. "The View from Academia." HydroVision International. July 2013.
- Garrett Monson. "Evaluating a Simple Model of Mass Transfer Across Bubbles." HydroVision International. July, 2013. Denver, Colorado.
- Hosein Foroutan, Savas Yavuzkurt. "Partially-Averaged Navier-Stokes Modeling of Turbulent Swirling Flow." Meeting of The American Physical Society. November 24, 2013. Pittsburgh, PA.
- Adam Witt, John Gulliver. "Void Fraction and Bubble Size in a Simulated Hydraulic Jump." APS DFD Annual Conference. November 25, 2013.
- Daniel Leonard. "Computation of Cavitating Flow in a Francis Hydroturbine." Fluid Dynamics Consortium. The Pennsylvania State University, University Park, PA. January 30, 2014.
- Chris Schleicher. "Design and Optimization of Micro-hydro Pumped Storage Schemes." March 27, 2014. Lehigh University.
- Andrew Hamann, Gabriela Hug. "Real-time Optimization of a Hydropower Cascade Using a Linear Modeling Approach." Power Systems Computation Conference. Wroclaw, Poland. August 19, 2014.
- Joe Rand. "Economic Analysis of Distinct Flow Proposals from Licensee and Stakeholder Groups. Yuba River Development Project Meeting. June 9, 2015 Sacramento, CA.

All 71 of these presentations have been provided in the quarterly progress reports.

Appendix E

Publications from Program

Publications in addition to final findings:

- *Environmental Hydraulics* – Christodoulou & Stamou (eds) © 2010 Taylor & Francis Group, London, ISBN 978-0-415-58475-3
Boat and bed load motion effects on velocity profiles measured with an acoustic Doppler current profiler
J. Petrie, P. Diplas & S. Nam- Baker Environmental Hydraulics Laboratory, Department of Civil & Environmental Engineering, Virginia Tech, USA & M.S. Gutierrez- Division of Engineering, Colorado School of Mines, USA
River Flow 2010-Dittrich, Koll, Aberle & Gesenhainer (eds) © 2010 Bundesanstalt fur Wasserbau ISBN 978-3-939230-00-7. “Local boundary shear stress estimates from velocity profiles measured with an ADCP.” J. Petrie, P. Diplas & S. Nam, Baker Environmental Hydraulics Laboratory, Department of Civil & Environmental Engineering, Virginia Tech & M.S. Gutierrez, Division of Engineering, Colorado School of Mines, CO, USA
- *River Flow* 2010-Dittrich, Koll, Aberle & Gesenhainer (eds) © 2010 Bundesanstalt fur Wasserbau ISBN 978-3-939230-00-7. “Effects of spatial variability on the estimation of erosion rates for cohesive riverbanks.” Soonkie Nam, John Petrie & Panayiotis Diplas, Virginia Polytechnic Institute and State University, Blacksburg, VA & Marte .S. Gutierrez-, Colorado School of Mines, CO, USA
- *Hydro Review*, “Building a New Team for the Hydro Industry.” Deborah Linke and Brenna Vaughn, Hydro Research Foundation, July.2011.
- Pavlo Rudenko, a current Fellow from Washington State University was highlighted in the wsutoday.wsu.edu on October 27, 2011. The article featured Pavlo’s participation at the 10-week Singularity University in California.
- News Release on Industry Partnerships. “Hydro Research Foundation Announces First partners for the Hydro Fellowship Program.” November 18, 2011.
- Article in NHA Today on Fellows on February 3, 2012.
- Jonathan Bartlett. “Brainpower for Hydropower.” Department of Energy Website. May 10, 2012. <http://www.doe.gov/articles/brainpower-hydropower>
- “Hydro Research Foundation Announces 10 Hydro Fellowship Recipients.” *HydroWorld.com*. Web. May 16, 2012.
- Adam M. Witt & John S. Gulliver. “Method for Predicting Oxygen Transfer at Low-Head Dams.” *Hydro Review*. June 2012.
- Garrett M Monson and John S. Gulliver. “Water quality stepped labyrinth weir option for aeration and boat passage.” *HydroWorld.com*. Web. September, 2012.
- Brian Campbell, Dan Zimmerle, Dr. Kimberly Catton. “Identification of spatial and topographic metrics for micro hydropower application in irrigation infrastructure.” *Colorado Water*. Volume 29, Issue 5. September/October 2012.

- Mark Raleigh, Karl Rittger, Courtney Moore, Brian Henn, James Lutz, Jessica Lundquist. "Remote Sensing of Environment." *SciVerse ScienceDirect*. Web. September 15, 2012.
- "Hydro Research Foundation accepting nominations for 2013 Fellowship Program." *HydroWorld.com*. Web. December 4, 2012.
- "Linke takes over as Hydro Research Foundation Executive Director." *HydroWorld.com*. Web. October 8, 2012.
- "Linke to take over as Hydro Research Foundation Executive Director." *Hydro Review*. December, 2012.
- John Petrie. "Data Evaluation for Acoustic Doppler Current Profiler Measurements Obtained at Fixed Location in a Natural River." *Water Resources Research*. January 2013.
- "Hydro Research Fellowship and Marine and Hydrokinetic Post-Doc." *DOE Breaking News Email Newsletter*. January 22, 2013.
- Michael George. "Scour of Discontinuous Blocky Rock." *USSD Newsletter*. March, 2013.
- "Hydro Research Fellows Announced." *Department of Energy News Blog*. Web published. June 20, 2013.
- "Two engineering graduate students win Hydro Foundation Fellowship." *Penn States News*. April 22, 2013.
- Bethany Duarte. "100 Little Moments." *Hydro Review*. July 2013.
- Melinda Harm Benson, Ryan Morrison, Mark Stone. "A Classification Framework for Running Adaptive Management Rapids." *Ecology and Society*. September 2013.
- Adam Witt, John Gulliver, Lian Shen. "Numerical Investigation of Void Fraction and Bubble Size in a Hydraulic Jump." *International Journal of Multiphase Flow*. July, 2013.
- Brenna Vaughn. "Meet a Hydro Research Foundation Fellow: Mark Christian and Hosein Foroutan." *NHA Today*. August 9, 2013.
- Jessie Wuerst. "Hydro Research Foundation Receives Grant from Avista Foundation for Student Fellowships." September 5, 2013.
- John Petrie, Panayiotis Diplas, Marte Gutierrez, Sookie Nam. "Combining Fixed- and Moving-Vessel Acoustic Doppler Current Profiler Measurements for Improved Characterization of the Mean Flow in a Natural River." *Water Resources Research Vol. 49, 1-15, doi:10.1002/crcr.20396*, 2013. July 2013.
- Melinda Harm Benson, Ryan R. Morrison, Mark C. Stone. "A Classification Framework for Running Adaptive Management Rapids." *Ecology & Society*. November 2013.
- Chris Schleicher. "Characteristics of a micro-hydro turbine." *Journal of Renewable and Sustainable Energy*. March 29, 2014.
- Brenna Vaughn. "Generating Hydropower's Future: HRF Working to Attract New Employees." *Hydro Review*. June 2014.
- "Power list: who will influence the hydropower sector in 2014." *Water Power & Dam Construction*. June 2014.

- Lee Roberts. “Nashville District Showcases its Projects for World’s Hydropower Experts.” *District Digest*. July 24, 2014.
- W.C. Schleicher, A. Oztekin. “Hydraulic design and optimization of a modular pump-turbine runner.” *Energy Conversion and Management*. 93 (2015) 388-398. January 13, 2015.

All 33 publications have been provided to DOE through the quarterly progress reports.

Appendix F

Other Products of Funding

- Andre Dozier was presented with two awards during his Fellowship. The IEEE Student Paper Award and the 1st Place Award for the HydroVision International Technical Papers of the Year Award for Project Management and Operations. Pictures attached.
- Pavlo Rudenko filed Patent Application (US/61654089) on December 5, 2013 for Nanostructures with Functionally Different Surfaces.

1 Appendix G

Information on States and Congressional Districts

States that received funding:

Alaska	Montana
Arizona	New Mexico
California	New York
Colorado	North Carolina
Georgia	Oregon
Idaho	Pennsylvania
Iowa	Tennessee
Maryland	Virginia
Massachusetts	Washington
Minnesota	

Congressional Districts that received funding:

University	District
Alaska Pacific University	AK-0
Northern Arizona University	AZ-1
University of California- Berkeley	CA-13
Colorado State University	CO-2
University of Colorado- Boulder	CO-2
Colorado School of Mines	CO-7
Georgia Institute of Technology	GA-5
University of Iowa	IA-2
University of Idaho	ID-1
University of Massachusetts- Amherst	MA-2
Worcester Polytechnic Institute	MA-2
University of Minnesota	MN-5
Montana State University	MT-0
University of North Carolina- Chapel Hill	NC-4
University of New Mexico	NM-1
Cornell University	NY-23
Oregon State University	OR-4
Carnegie Mellon University	PA-14
Lehigh University	PA-15
Pennsylvania State University	PA-5
University of Tennessee	TN-2
Virginia Tech	VA-9
Washington State University	WA-5
University of Washington	WA-7

1 Appendix H

Advisors- Academic Advisors- 37 Total

Dr. David Ahlfield

University of Massachusetts-Amherst

Dr. Roberto Albertani

Oregon State University

Dr. Mustafa Aral

Georgia Tech

Dr. Amit Bandyopadhyay*

Washington State University

Dr. Michael Barber

Washington State University

Dr. Ted Brekken*

Oregon State University

Duncan Callaway

University of California, Berkeley

Dr. John Cahoon

Montana State University

Dr. Gregory Characklis

University of North Carolina- Chapel Hill

Dr. Rich Christie*

University of Washington

Dr. John Cimbala

The Pennsylvania State University

Dr. Panayiotis (Panos) Diplas

Virginia Tech

Dr. Fritz Fiedler

University of Idaho

Dr. Mengistu Geza

Colorado School of Mines

Dr. John Gulliver*

University of Minnesota

Roy Haggerty

Oregon State University

Slav Hermanowicz

University of California, Berkeley

Gabriela Hug

Carnegie Mellon University

Dr. John Labadie

Colorado State University

Jules Lindau

Penn State University

Dr. Jessica Lundquist

University of Washington

Dr. Paul Mathisen

Worcester Polytechnic University

Dr. Mike Mooney

Colorado School of Mines

Alparslan Oztekin*

Lehigh University

Roderic Parnell

Northern Arizona University

Dr. Marcela Politano

University of Iowa

Dr. Christine Shoemaker

Cornell University

Fotis Sotiropoulos

University of Minnesota

Dr. Jerry Stedinger

Cornell University

Dr. John Steele

Colorado School of Mines

Dr. Mark Stone

University of New Mexico

Brett Towler

University of Massachusetts - Amherst

Elowyn Yager*

University of Idaho

Savas Yavuzkurt

Penn State University

Dr. Edith Zagona

University of Colorado- Boulder

Dr. Dan Zimmerle

Colorado State University

Savas Yavuzkurt

The Pennsylvania State University

* Are professors who have advised more than one student in the program.

2 Appendix H

Advisors- Industry Mentors- 36 Total

Steve Amaral

Alden Research Laboratory

Dr. George Annandale

Golder Associates

Steve Barton

Bonneville Power Administration

Norm Bishop

Knight Piesold Consulting

Stuart Bridgeman

Hatch

Jeff Burnham

Flow Science

Scott Cotner

United States Army Corps of Engineers

Curt Dotson

Grant County PUD Fisheries

David Elwood

HDR, Inc.

John Esler

Portland General Electric

Steve Hammond

Duke Energy

Gabriela Hug

Carnegie Mellon University

Dave Hulse

United States Bureau of Reclamation

George A. Galleher

Duke Energy

John Germann

US Bureau of Reclamation

Dana Jeske

Grant County PUD Fisheries

Tom Lowry

Sandia National Labs

Patrick Maher

Avista Corporation

Michael Manwaring

MWH

Adam Mazurkiewicz

San Francisco Water, Power, and Sewer

Rick Miller

HDR, Inc.

Debbie Mursch

Asltom

Dr. Vince Neary

Oak Ridge National Laboratory

Doug Ott

AK Energy Authority

Shaun Parkinson

Idaho Power

Minal Parekh

US Army Corps of Engineers, Risk Management Center

Guy Paul

Avista Corporation

Mike Pulskamp

United States Bureau of Reclamation

Cindy Raskowski

Pacific Northwest National Lab

Michel Sabourin

Alstom

Dr. Michael Sale

Low Impact Hydropower Institute

Del Smith

United States Bureau of Reclamation

Nathan Snorteland

United States Army Corps of Engineers

Wayne Todd

United States Army Corps of Engineers

Andrew Ware

Weir American Hydro

Steve Wenke

Avista Corporation

3 Appendix H

Advisors- Steering Group Members- 14 Total

- **Linda Church-Ciocci**-National Hydropower Association
- **John Etzel**- US Army Corps of Engineers
- **Carol Goolsby**-Duke Energy
- **Dr. John Gulliver**- University of Minnesota
- **Dr. Paul Jacobson**- Electric Power Research Institute
- **Diane Lear**- National Hydropower Association
- **Patrick March**- Hydro Performance Processes Inc.
- **Kerry McCalman**- US Bureau of Reclamation
- **Sonya Reiser**- Knight Piesold Consulting
- **Gerry Russell**- Weir American Hydro
- **Dr. Michael Sale**- Low Impact Hydropower Institute
- **Dr. Brennan Smith**- Oak Ridge National Laboratory
- **Carl Vansant**- HCI Partners
- **Dr. Larry Weber**- University of Iowa

Appendix I

Topics and Areas of Interest

This is sample from one of the funding years to demonstrate topic areas of interest.

2013 Topics and Areas of Interest for the Hydro Fellowship Program

Awards under the Hydro Fellowship Program for 2013 will focus on topics directly related to the improvement of **conventional hydropower and pumped storage hydropower** technologies and operations. Research topics submitted for consideration in applications for 2013 awards should strongly relate to one or more of the topics in the following list.

Research categories of interest and topics within categories are listed in order of preference (i.e., first listed are highest priority for the 2013 funding). Priority will be given to applicants working toward masters' degrees in mechanical, materials, or electrical engineering fields, but doctoral students or masters' students working in other disciplines are welcome to apply. Applicants should identify the topic number(s) to which their proposal most directly relates.

Advances in Hydropower Equipment

1. Turbines with environmental benefits such as improved fish passage survival rates
2. Advanced turbines for energy and environmental performance
3. Design of standardized low-head turbines (e.g. drop-in turbines) having minimal environmental impact
4. Tools to assess the role of hydropower in power system stability and reliability
5. Resource assessment for power potential at closed conduits
6. Advances in instrumentation and controls [protection, automation, governors, Supervisory Control and Data Acquisition (SCADA)]
7. Generator design for quick start and frequent cycling
8. Predictive Maintenance/Repair and Condition Monitoring
9. New technology to increase energy efficiencies of turbines under a wide range of operating conditions, particularly related to support of intermittent energy sources
10. Innovative methods to reduce the cost of underground excavation in project construction
11. Advances in Pump-Turbines, and Related Technologies for use in pumped-storage hydropower and renewable energy storage
12. New technology to increase water-use efficiency
13. Improvements in pumps and/or reversible pump-turbines
14. Improvements in variable speed generators
15. Advances in generators for use with low-head turbines
16. Improvements in pumped storage planning and design

17. Inline turbines for installation in pressurized water distribution or conveyance systems
18. New technology to enhance downstream water quality
19. Innovative integration and control mechanisms for power systems with various types of renewable energy

Advanced Material Applications

20. Innovations in coatings for water conveyance structures
21. Cavitation and erosion-resistant materials
22. Improvements to environmentally compatible oils and lubricants
23. Advances in generator insulation systems
24. Advances in stator core materials

Environmental and Societal

25. Atmospheric emissions from Reservoirs, including GHG's and evaporation.
26. Mitigation effectiveness studies
27. Management strategies for invasive species
28. Fish passage and protection of migratory species
29. Adaptation to climate change and variability/extreme events
30. Aquatic habitat and environmental flow requirements
31. Resolution of conflicts with tribal/indigenous peoples perspectives
32. Sedimentation and erosion control
33. Shoreline and land management/recreation
34. Tools for environmental optimization
35. Water quality management and mitigation
36. Endangered species protection and management of invasive species

Project Implementation, Management and Operations

37. Hydraulic performance testing and improved flow measurement
38. Operational improvements to maximize ancillary benefits
39. Innovations in pumped storage design and operation
40. New technology for cost effective, faster hydro project implementation
41. Improved methods for knowledge capture and transfer in hydropower workforce transitions
42. Turbine/generator equipment failure forensics and root-cause analysis
43. Innovations in planning and strategies for rehabilitation for increases in efficiency and capacity
44. Human factors considerations for safe operation of hydropower facilities

Protection of Critical Hydropower Infrastructure

45. Development of risk assessment and management tools for critical hydropower infrastructure
46. Development of critical hydropower infrastructure protection strategies including physical security and cyber security for hydropower

47. Improvements in the assessment of effectiveness of critical hydropower infrastructure protection methods and technology

Market Trends and Strategies

48. Certification and verification of hydropower as green energy (Renewable Energy Credits, etc.)
49. Operational costs to hydro for supporting intermittent renewables
50. Resource assessment and validation
51. Economics of pumped storage
52. Assessment of conventional and pumped-storage hydropower's benefits to transmission systems
53. Renewable energy integration strategies using pumped storage and conventional hydro
54. Innovative market structures that recognize hydropower's ancillary benefits
55. Pricing of hydroelectricity and cost recovery for hydroelectric generation projects

Simulation and Optimization Tools

56. Simulation and optimization models for machine and operational improvements
57. Optimization tools for realizing the full potential of pumped storage projects for provision of grid services.
58. Physics-based modeling and real-time analysis of hydropower systems integrated with other non-hydro renewables, fossil, and/or nuclear power systems.

Water Management Innovations

59. Long-term forecasting for precipitation, runoff, and storage, particularly Probable Maximum Precipitation/Probable Maximum Flood
60. Multi-purpose water management systems, including use of off-channel water storage
61. Reliable surveillance and monitoring of hydropower dams (even during power outages) including rapid notification of developing emergencies such as floods, structural problems, leaks, security breaches, etc.
62. Structural and geotechnical aspects of hydropower dam safety
63. Advanced weirs for flow re-regulation and aeration

New Research Topics

64. Other research topics that will directly contribute and be of value to the hydro industry