



MONTANA NSF EPSCoR NEWSLETTER

**CREWS
YEAR 2
HIGHLIGHTS
2020**



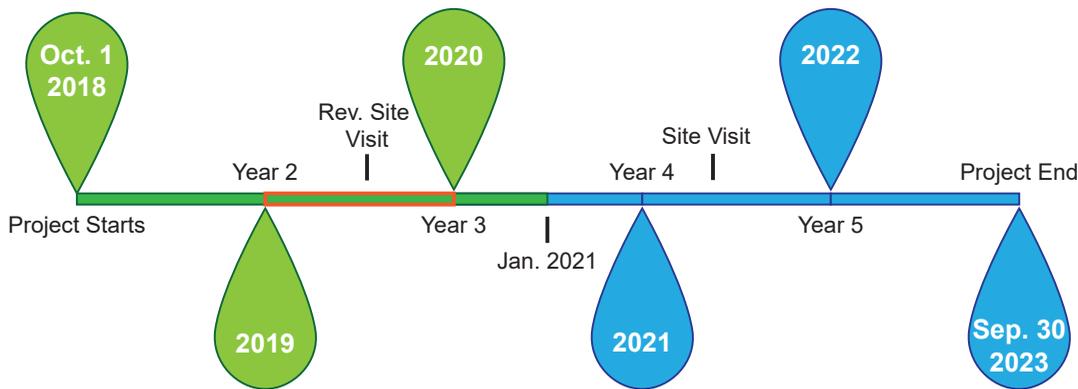
Research on the Upper Clark Fork River (see page 3), Judith River Watershed (see page 4), and Powder River Basin (see page 5) addresses the origin, persistence, and transformation of contaminants in water, and their impact on ecological and social systems. Shown above, CREWS Postdoc Rafael Fiejo de Lima breaks the ice off of a sensor post in the Upper Clark Fork River before retrieving a submerged autonomous sensor bundle. *Photo credit: Claire Utzman.*

YEAR 2 HIGHLIGHTS

This Special Issue of the Montana NSF EPSCoR newsletter provides a summary of Year 2 activities and progress for the RII Track-1 Consortium for Research on Environmental Water Systems (CREWS) project. CREWS, supported by the National Science Foundation under Award OIA-1757351, is a five-year \$20M project that explores how changing compositions and levels of nutrients and contaminants affect water quality

from soils and rivers to local communities that rely on clean water. The project focuses on three Montana landscapes where water and economy are inextricably linked and creates opportunities in workforce development, innovation, and entrepreneurship. See the timeline below for an overview of where activities described in this newsletter sit on the project timeline (highlighted section) as well as other major project milestones and dates.

MT NSF EPSCoR CREWS PROJECT TIMELINE



Timeline of the Montana NSF EPSCoR RII Track-1 CREWS project illustrating major dates and milestones. This Special Issue newsletter highlights activities that occurred in Year 2 of the project, noted in orange on the timeline.





CREWS BY THE NUMBERS

YEAR 2 OUTCOMES OF MONTANA'S NSF EPSCoR RII TRACK-1 PROJECT

53 total faculty, **41** postdocs and graduate students, and **42** undergraduate students involved with the CREWS project in Year 2

\$1.2 MILLION IN GRANTS AWARDED – Cumulative total amount of grant funding awarded to CREWS researchers by the end of Year 2

14 SEED GRANTS – Total number of seed grants awarded in Year 2. For more information about these seed grants, see Page 3

52 PUBLICATIONS – Cumulative total number of publications released by CREWS researchers by the end of Year 2

58 PARTNERS AND COLLABORATORS – Total number of CREWS partners and collaborators in Year 2. For the full list of external partners and collaborating institutions see Page 12

\$3.5 MILLION IN CO-FUNDING – Total NSF EPSCoR co-funding awarded to Montana in Year 2

DIRECTORS UPDATE

The impacts of COVID-19 aside, in the second year of the project CREWS maintained the intense pace we established in the first year and met the large majority of milestones and outcomes - and exceeded many. We could not be prouder of how our teams worked together to keep the project on track. Sensors were deployed, publications are out, and many grant proposals were submitted. Many challenges were creatively mitigated, but a few were delayed. The social science team adeptly adjusted to a new reality in which in-person interviews were not safe or consistently possible. Our tribal college partners deftly adapted to focus on community needs. Two of our faculty hires were put on hold by a university-system-wide hiring freeze, but these conversations continue. But, the team used technology to stay connected, conducted field and lab work following new guidelines, and stayed productive with a minimum of in-person meetings. With the endorsement of NSF, we moved our Year 2 Reverse Site Visit, a formal project evaluation, to a video conference format with only one week to make the change. The CREWS team, NSF, and the review panel all embraced the change, and the team received great feedback that we have incorporated into the project. Now, early in Year 3, the CREWS project is on track. The resilience of this team is impressive.

Ray Callaway & Todd Kipfer

CREWS YEAR 2 SEED GRANTS

RESEARCH AWARDS

- *Seasonal anoxia under winter ice cover enhances mobilization, methylation and downstream transport of mercury from Georgetown Lake, Montana.* MSU PI John Dore and co-PI Eric Boyd.
- *Effect of nitrate and sulfate on the biotransformation of selenium, microbial diversity and multi-domain biofilm formation: implications for the remediation of selenium-laden waters.* MSU PI Erika Espinosa-Ortiz, and co-PIs Rebecca Muller, Ellen Lauchnor, Robin Gerlach, and Brent Peyton.
- *Preventing Environmental Impact of Metals Extraction Using Biocompatible, Magnetic Nanomaterials.* MTU PI Katie M. Hailer.
- *ArduiNMR: a low cost infiltration sensor.* MSU PI Trevor Irons and co-PI Xiaobing Zhou.
- *Technology Platform for High-Spatial-Resolution Monitoring of Water Quality with Redundant in situ Micro-Sensors.* MSU PI Stephan Warnat.

- *Interactive effects of heavy metals and temperature on the survival, growth, and thermal tolerance of salmonfly nymphs from the Upper Clark Fork River.* UM PI Art Woods.
- *Synergic field identification of heavy metal contaminants in mining tailings and exposed sediments using laser-induced breakdown spectroscopy and hyperspectral spectroscopy.* MTU PI Xiaobing Zhou and co-PIs Marvin Speece and Gary Wyss.

TRIBAL COLLEGE AWARDS

- *A STEM Summer Camp for Secondary Students on the Flathead Reservation.* SKC PI Heather Bleecker.
- *Building Chemistry Curriculum Laboratories for Natural Resources and Environmental Science.* LBHC PI Neva Tall Bear.
- *Little Bighorn River Watershed Management Plan: Utilizing GIS technologies and analysis.* LBHC PI Emery Three Irons.

WORKFORCE DEVELOPMENT AWARDS

- *Promoting Community Resilience Through Understanding: Social Perceptions of Water Quality and Contamination in the Upper Clark Fork River Watershed.* UM-W PI Arica Crotofof.
- *CREWS Montana State University Billings Water Quality and Environmental Impact Undergraduate Research Internship Program.* MSU-B PI Matt Queen.
- *Baseline Assessment of Phase Four Proposed Remediation on the Upper Clark Fork Near Galen, Montana.* UM-W PI Robert C. Thomas.
- *Stakeholder visions of the past, present, and future of water quality in Montana coal country.* RMC PI Luke Ward.



A map illustrating CREWS partner institutions. CREWS was developed as a partnership between the University of Montana (UM), Montana State University (MSU), Montana Technological University (MTU), Salish Kootenai College (SKC), and Little Big Horn College (LBHC). Through competitive seed funding opportunities, new higher education partners include Carroll College, University of Montana Western (UM-W), Montana State University-Billings (MSU-B), and Rocky Mountain College (RMC).



Riley Logan, PhD student at Montana State University, preparing to collect hyperspectral imaging data along the Upper Clark Fork River in Montana. *Photo credit: Jill Logan.*

UPPER CLARK FORK RIVER

CREWS researchers are studying ecological integrity along a 200-km stretch of the Upper Clark Fork River (UCFR) combining field sampling, sensing activities, lab-based research, and modeling. These activities are complimented by research on engineering solutions to water quality issues on the UCFR and social science studies of community response to water quality issues. “Our team of scientists working on the UCFR is excited about cross-pollination of ideas among participants, says site-lead and co-PI Maury Valett. “The interface among systems science, food web ecology, and nanoparticle transport provides an exciting opportunity for discovery.” Year 2 of the project wraps up a successful field season that expanded upon baseline work conducted in the first year of the project, and highlights significant progress in the lab and an expanded network of partners in the project.

The summer 2020 field campaign expanded monitoring efforts, using autonomous in situ sensors to measure carbon dioxide, dissolved oxygen, nitrate and conductivity -- pairing these with in-person sampling of water volume, depth, pH, and sample collection for lab-based analysis. Water samples were analyzed in the lab for nutrients (nitrogen, phosphorous, carbon) and for metals and arsenic. CREWS researchers also tracked the growth of river algae that often forms nuisance blooms and conducted drone-based hyperspectral imaging to measure algal abundance on the UCFR.

Food web researchers sampled river macroinvertebrates and their food sources to measure how energy, nutrients, and contaminants move from water and sediments into riverine biota. These sampling activities will quantify invertebrate community structure, patterns of stable isotopes, metal burdens, and invertebrate gut contents. CREWS researchers collaborated with Montana Fish Wildlife and Parks to estimate the population of fish species across the same

six sites used for invertebrate studies and measure metal content and stable isotope composition in fish gut and tissue. This sampling will play a crucial role in understanding how contaminants bioaccumulate in food webs.

Research on the composition of naturally-occurring colloidal particles suggests they may be susceptible to magnetic fields associated with technical metal recovery approaches, which may provide an effective and novel technology for cleaning environmental waters. In the lab, CREWS researchers built and tested a pilot-scale Continuous Flow Metal Recovery (CFMR) system. The reactor uses synthetic nano-composite particles and natural materials to extract metals from solution. The research team continues to explore ways to improve capture efficiency for copper and other metals.

CREWS awarded three seed awards for research and education projects related to the Upper Clark Fork River. Researchers at UM are studying the interactive effects of heavy metals and temperature on the salmonfly nymphs. Undergraduate students at UM Western are conducting a baseline analysis of stream parameters for a stretch of the UCFR near Galen. And undergraduate students at UM Western are researching social factors and community resilience around water quality in the Warm Springs Pond area.

CREWS faculty, students, and postdocs are collaborating with Montana agencies, NGOs, and private companies to carry out this work, share monitoring data, and align CREWS research with State priorities. These collaborations make up the **Upper Clark Fork Working Group** (UCFWG), which continued to develop and grow over the course of Year 2. The mission of the UCFWG is to facilitate shared data, information, and activities among participants involved in the remediation, restoration, research, and monitoring of the Upper Clark Fork River and its tributaries.

For more information please see: ucfwg.org.

JUDITH RIVER WATERSHED



Katelyn Duncan from the Walker Group at MSU stands in front of a time-correlated single photon counting (TCSPC) spectroscopy set-up. This set-up is used to measure the fluorescence of lifetimes of the electrons' excited state. *Photo credit: Katelyn Duncan*

In the Judith River Watershed (JRW), CREWS researchers and students from MSU, UM, and MTU are determining key controls on the movement of nitrate and pesticides through soils, groundwater, and streams as well as understanding community experiences with water quality policy and management. In Year 2 of the project, the JRW team of scientists and students continued and expanded data collection and compilation from Year 1. Members of the team completed three field campaigns over the course of the summer to

deploy stream sensors and collect a range of riparian zone water samples along Louse Creek and Porter Creek in the Moccasin area. As part of the field campaigns, the team also conducted drone flights over study sites to identify in-stream vegetation using hyperspectral imaging and identify multispectral patterns and topography in riparian corridors.

Modeling efforts based on these field data were also a key focus in Year 2. CREWS Team members used lysimeter data in models of nitrate and water use efficiency and developed a working model of seasonal water movement and denitrification based on nitrate concentration and isotope data in soils, streams, and groundwater. Researchers and students worked with partners from the Central Agricultural Research Center (CARC) and the state Mesonet program to install a snow scale in Fall 2019, and snow observations will be made in tandem with a new NASA SnowEx effort at CARC during Winter 2020-21.

In the lab, researchers assembled a benchtop reverse osmosis system at MTU to assess the interaction of membranes and biofilms with pesticides and related compounds. They characterized biofilms grown under different nutrient conditions with synthetic organics and learned that bacteria responsible for biofilm growth will absorb synthetic organic solutes used as pesticides and, in some cases, metabolize those solutes. In addition, the team made considerable progress in understanding the mechanisms responsible for synthetic organic accumulation in biological membranes and possible consequences for environmental persistence as well as completed experiments documenting the photocatalytic behavior

of iron oxides and synthetic compounds for improved photochemical denitrification.

Social scientists from MSU documented how the management of public water supplies affect community resilience by interviewing stakeholders and analyzing historical and contemporary documents like newspapers and government reports. The team interviewed 35 community leaders about their experiences and analyzed several hundred pages of historic documents to understand the evolution of drinking water issues. From this analysis, they found that small towns across the region take a number of approaches to cope with water quality and supply challenges, and differ in their capacities to comply with safe drinking water regulations. Moving forward, the team is analyzing these results to inform the creation of a survey next year that will be developed in collaboration with UM social scientists.

The JRW Working Group, composed of individuals from MSU-Extension, the Natural Resources Conservation Service, the Central Agricultural Research Center, and the Montana Department of Agriculture, was convened for the first time in Year 2, with one in-person meeting in early 2020 and a second virtual meeting in June 2020. The purpose of the JRW Working Group is to engage in an active dialogue about specifics of research activities, implications of findings, and relevance for communities in the watershed.



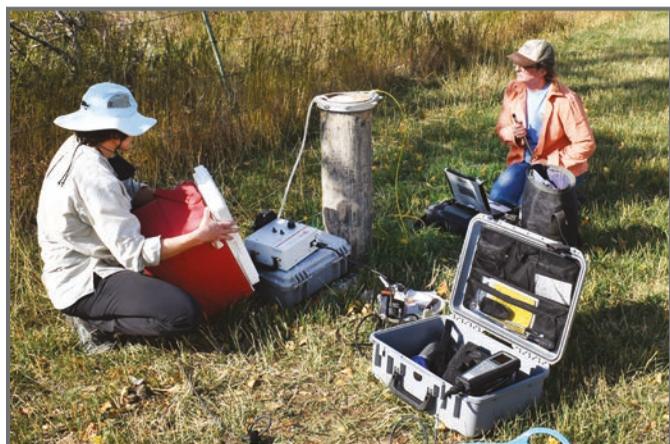
CREWS researchers and students from UM and MSU work with sensors and data loggers on an experimental reach on Porter Creek just east of Moccasin, MT. *Photo credit: Stephanie Ewing*

POWDER RIVER BASIN

CREWS activities in the Powder River Basin (PRB) have been affected more by the COVID-19 pandemic in Year 2 than at any other field-site. Nevertheless, the team's work continues to proceed with the long-term plan and they are confident that they will make up for lost time over the course of the project.

The PRB team identified and secured access to land on Rosebud Creek. This was spearheaded by Montana Tech and the Montana Bureau of Mines and Geology and led to the drilling of six wells in drainages adjacent to the creek on private land. These wells are down-gradient from coal-mining spoils and disrupted aquifers. These ground water sources empty into Rosebud Creek upstream of the town of Colstrip, which must manage water quality. Wells were placed in dry drainages originating on land reclaimed in the 1980's from open air coal mining and two wells were placed in drainages that have not been impacted by coal mining. These wells will provide powerful comparative insight into the impact of land reclamation on groundwater-surface water exchange mechanisms.

An important focus of the PRB is understanding conditions that control gypsum dissolution, given that this process is responsible for high sulfate loadings in ground and surface waters passing through landscapes that have been disrupted by coal mining activity in Southeast Montana. To address these questions, researchers at MSU examined how charged surfactants affect gypsum dissolution. As part of these studies the team employed bulk solubility and ionic strength measurements as well as surface-specific, nonlinear vibrational spectroscopy experiments. Initial findings suggested that surfactant charge affects dissolution mechanisms. Anionic surfactants such as sodium dodecyl sulfate (SDS) destabilize the gypsum-aqueous interface



Ann Marie Reinhold sets up to sample a new groundwater well next to Rosebud Creek with Liddi Meredith. *Photo credit: Stephanie Ewing*



Liddi Meredith narrates the history of coal mining and mine reclamation as Rob Walker looks on, marveling at the chemical ramifications of her words. *Photo credit: Stephanie Ewing*

promoting gypsum dissolution and forming mesoscopic calcium-SDS clusters in bulk solution. Furthermore, surface-specific vibrational measurements suggest that SDS will adsorb to the surface, disrupting interfacial water structure. More generally, questions about solute adsorption to salt-aqueous interfaces are largely unexplored in the literature so these initial results are building a foundation to understand how chemistry occurring at the solid/water interface impacts water quality in a wide range of environmentally relevant interfacial systems.

Sampling of soils on the Crow Reservation for arsenic and sulfate began in 2019, but activities were halted due to COVID-19. Before the pandemic began, individuals from MSU and LBHC were meeting monthly with the Crow Environmental Health Steering Committee at LBHC and the team sampled well sites across the Crow Reservation, with water from these wells being tested for arsenic and sulfate. The analyses showed strong correlation between sulfate and arsenic concentrations, and future work will determine if thioarsenate and thioarsenite species are present in these samples.

CREWS awarded three seed grants to expand activities in the PRB. One of these seed grants, awarded to a researcher at MSU, will test fungal biofilms as sinks to transform and remove oxidized selenium from contaminated groundwater. The second seed grant was awarded to a researcher at Rocky Mountain College (RMC) who— together with several RMC undergraduates —will conduct interviews with residents on Rosebud Creek, and other streams and rivers impacted by coal mining activity, to assess perceptions about the relationship between water quality and coal mining activities. The third seed grant was awarded to a researcher at Little Big Horn College (LBHC) to support the use of GIS technologies and analysis in developing a Little Bighorn River watershed management plan.

NATURAL RESOURCE SOCIAL SCIENCE

CREWS social science researchers are studying community resilience -- how communities adapt and respond to stressors or disturbances, such as environmental contamination. Researchers from UM and MSU are working in communities from the JRW and UCFR study sites to carry out this research, including Denton, Harlowton, Judith Gap, Roundup, Anaconda, and Deer Lodge.

The Natural Resource Social Science team has conducted 91 semi-structured interviews with community members and leaders from the selected communities in the JRW and UCFR. COVID-19 forced researchers to do a major pivot in how these interviews are conducted, but by the conclusion of Year 2, these interviews have been transcribed and analysis is underway. Findings from these interviews will direct the next phase of the social science work on the project, the development of a survey instrument to quantify connections between risk perceptions, trust, and community resilience.

A key product of Year 1 and 2 work from the JRW team are two manuscripts based on data collected in the Judith River Watershed. The manuscripts report on processes that shape interactions between public water supply management and community resilience.

In other social science activities, researchers at Salish Kootenai College (SKC) are exploring the impact of outreach activities around 'water' on youth on the Flathead Indian Reservation. They are developing an application/game to understand how 4th and 5th graders value water resources.



Grete Gansauer, a PhD student at MSU and member of the NRSS team, stands in front of a water tank in Harlowton, MT. *Photo credit: Grete Gansauer*

The app is based on findings from interviews conducted in Year 1 of the project and will be launched in conjunction with a quantitative survey.



Looking south on Main Street in Anaconda, Montana. Anaconda was originally established as a smelting town, where copper ore was processed from the nearby mines in Butte. In 1980, the Atlantic Richfield Company (ARCO) shut down the mining operations, and three years later the EPA designated Anaconda and the surrounding area a Superfund site. Cleanup operations are ongoing and will be shaped, in part, by a recent agreement between ARCO and Anaconda-Deer Lodge County. The CREWS Natural Resources Social Science (NRSS) research team at UM is currently conducting a study in Anaconda, and the nearby community of Deer Lodge, to examine how communities bounce back after water contamination issues and improve both soil and water quality for future generations.

ENVIRONMENTAL SENSORS, SYNOPTICS, AND SIGNALS

The CREWS Environmental Signals, Synoptics and Sensors team, or ESSS in short, amplifies efforts by many other research teams at MSU and UM, as well as industry partners. ESSS develops and deploys sensor technology and collects data used in powerful inferential modeling. These technologies support research at the three study sites and provide crucial data for understanding the environmental processes that dictate the life cycle of water contaminants and river algae. ESSS activities focus on developing new and more cost-effective environmental sensor systems and coordinating autonomous in-situ sensor and remote optical sensor deployment, data management of resulting signal and synoptic data, and software development and analysis.

Following the initial sensor deployments in Year 1, ESSS Year 2 activities focused on coupling advanced informatics and sensor data to design experiments for understanding the distribution of contaminants and their influence on river ecosystems. Although COVID-19 restrictions slowed field work, the team used the Year 2 summer field season for tighter spatial and temporal integration of data gathering by the various groups. ESSS teams emphasized using in-situ sensors that measure carbon dioxide, dissolved oxygen, nitrate, and conductivity to understand how river contaminants vary over the course of a day are linked to river properties. The team also used remotely operated



Stephanie Ewing and PhD student Caitlin Mitchell calibrate a multimeter in preparation for sampling a JRW creek. A SUNA sensor in the foreground awaits deployment. The sample will serve to verify the sensor measurement and provide ancillary data. *Photo credit: Ray Callaway*

drones with advanced hyperspectral imaging systems to track the growth of algal blooms in the river. In addition, CREWS awarded seed awards to researchers at MSU and MTU to develop sensors for monitoring water quality.

SYSTEMS ECOLOGY

The Systems Ecology and Earth Sciences team, also known as SEES, examines how solutes – including nutrients and pesticides – are delivered to and transformed by soils, aquifers, and riparian zones in ways that govern the water quality of rivers and streams. The team has adopted an expansive approach to reactive transport modeling within and among these different hydrogeomorphic process domains. It is exploring the utility of Damkohler indices for describing reactive transport dynamics that are a result of variability in the rates of water movement and reaction rates arising from heterogeneity in process domain properties. The SEES team has also developed a mechanistic computer model to systematically test the relative importance of key factors governing reactive transport on water quality within and among process domains

Field activities in the UCFR and JRW supported the goals of the SEES team in Year 2. Researchers and students from

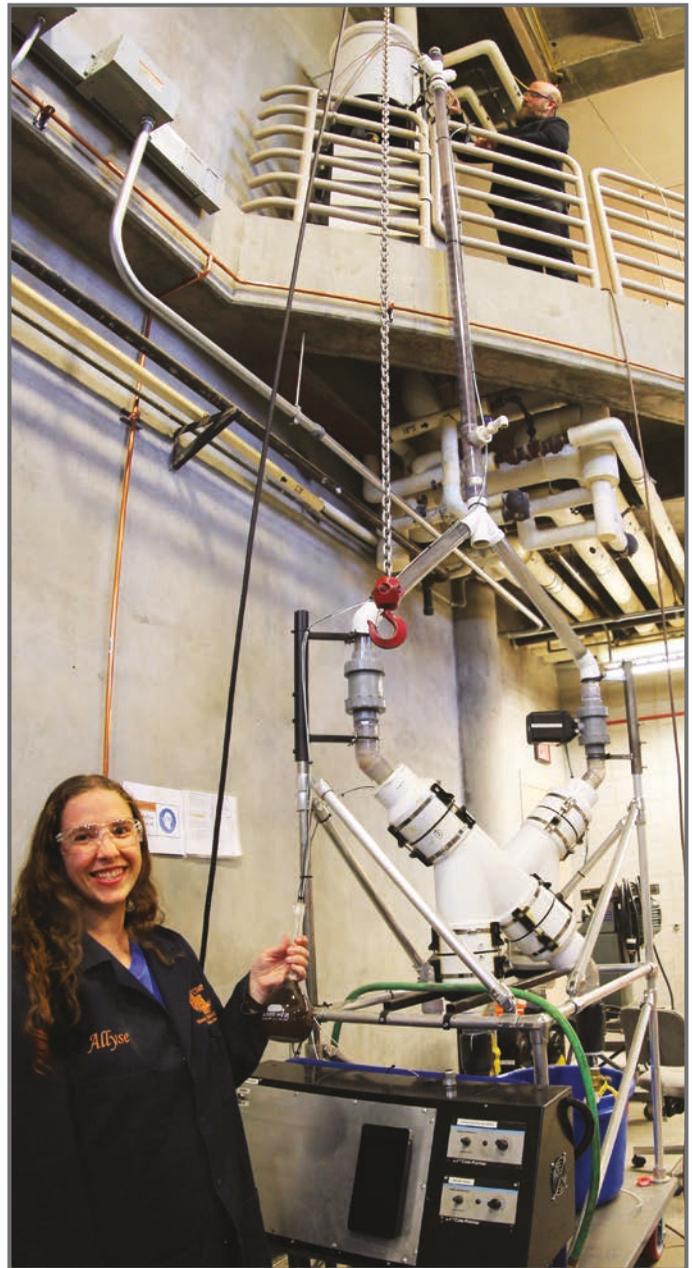
UM and MSU continued the extensive use of sensors to acquire the data necessary to quantify reaction rates of nutrients and contaminants of interest. The transport and processing of nitrate remained a focus for both the UCFR and JRW research sites. The SEES team also generated a white paper focusing on three different areas: 1) clear articulation of the theoretical framework linking reactivity and transport, 2) addressing a scaling approach to link biogeochemical reactions to water quality patterns at the landscape scale, and 3) generating hypotheses with testable predictions linked to the ongoing CREWS projects. Collectively, the interdisciplinary approach of the SEES team is operationalizing theory and concepts from research domains ranging from chemical engineering to classical ecology to develop a quantitative, comprehensive, and integrated framework describing how coupled hydrologic and biogeochemical continuums link soils, aquifers, streams, and rivers.

MOLECULAR ENGINEERING

Molecular Engineering and Environmental Science, or MEES, is an integrative effort that focuses on the behavior of water contaminants in diverse environments across the three study sites. Research activities span chemistry, physics, and materials engineering and address knowledge gaps related to impaired environmental water. MEES teams target greater understanding of environmental water contaminants and their effects on biological activity and interactions with natural and engineered materials.

In Year 2, the MEES team met or exceeded its original plans. At MSU and MTU, team members collaborated to use Time Correlated Single Photon Counting Spectroscopy (TCSPCS) to measure herbicide emission lifetimes in water and assess herbicide partitioning into biological membranes, and researchers at UM and MTU worked together to identify poorly understood components of water contamination, natural and synthetic nanoparticles, and how to remove them.

Beyond these collaborations, MEES team members continued research activities in their respective labs. At MSU, the team conducted groundbreaking research on the underpinnings of bioaccumulation in model biological membranes. They also compared the photocatalytic activity of iron oxides and oxyhydroxides to TiO₂ to improve the photocatalysis of nitrate reduction. At MTU, the MEES team tested a reverse osmosis (RO) system for a protocol to test biofouling of RO membranes under different conditions, complementing studies at MSU, and accelerated the development of the Continuous Flow Metal Recovery (CFMR) system and synthesis of magnetic nano-composite ion exchange media. The MTU team also worked on developing denitrification filter material to assist microorganisms in reducing nitrate contamination and made progress towards fabrication of an engineered photocatalytic system for denitrification. Finally, MEES team members at UM focused on size fractionating of water samples to separate suspended particulate matter, colloidal particles, and dissolved solutes during Year 2.



Graduate student Teagan Leitzke and postdoc David Hutchins work on the Continuous Flow Metal Recovery System at MTU. Photo credit: Jerry Downey

A convergent research approach integrates faculty and students from four teams: 1) systems ecology and earth sciences; 2) molecular engineering and environmental science; 3) environmental synoptic signals and sensors; and 4) natural resource social sciences to respond to nationally relevant water quality problems.

OUTREACH

The CREWS project emphasizes the sharing of project findings and communications through its website, newsletter, and social media posts, as well as through educational programs, activities, and presentations. Montana NSF EPSCoR was instrumental in planning and hosting the 2019 statewide STEM Summit, which brought together individuals representing K-12, higher and out-of-school education, industry, government, and nonprofits to discuss the STEM pipeline in Montana. The Small Town STEM program, developed by Montana NSF EPSCoR and the MSU Science Math Resource Center, grew its outreach partnership with the Montana Afterschool Alliance during Year 2 and hosted a “Sensing for Science” workshop for out-of-school-time educators. The Sensing for Science activities, which were created by CREWS outreach partners and researchers, allow kids to explore different sensors in action by answering questions about what sensors are, how they work, and how they are used in scientific research.

In addition to the educator workshop, Sensing for Science was featured in spectrUM Discovery Area’s mobile “Water” exhibition that traveled to western Montana communities and will be featured with other activities in the planned “Water Learning Ecosystem” educational experience being developed by spectrUM and its partners. CREWS outreach partners also hosted a STEM education workshop for youth leaders from the Lewistown Boys and Girls Club to demonstrate activities focused on water quality, including the CREWS Junior Researcher acid mine drainage activity developed by an MSU seed grant recipient. COVID-19 limited the ability to host in-person events for much of Year 2, but the team continues to work with its partners to host



Exhibit fabricator and spectrUM Discovery Area staff complete installation of the Clark Fork River water table exhibit in spectrUM’s new location at Missoula Public Library. Photo credit: spectrUM

virtual presentations and meetings, including findings from the STEM Summit 2019, a conversation about recruiting girls into the STEM pipeline, and a virtual workshop for teachers that will highlight CREWS research and activities.

COMMERCIALIZATION INTERNSHIP PROGRAM

CREWS launched an Innovation and Commercialization Internship Program in Year 2, providing two graduate students from UM and one postdoc from MTU opportunities to explore the commercial potential of their research or innovation ideas. The interns’ ideas included testing the feasibility of Continuous Flow Metal Recovery System Technology (CFMR) for biomedical applications, examining the commercial potential of a data sharing app for anglers and academics, and quantifying the market interest in a prototype alkalinity sensor for freshwater systems. To

better understand the commercial potential of these ideas, interns participated in a workshop through the UM NSF I-Corps Site to learn about customer and market discovery, how to build a template for a commercialization plan, guidance for engaging with partners, and how to complete other tasks appropriate to the specific innovation idea. A new set of interns in Year 3 will explore the commercialization potential for innovative ideas in remote sensing, community engagement, freshwater ecology, and STEM education.



Seventh grade girls from Gardiner Public Schools and high school girls from Salish Kootenai College Upward Bound pose outside the Montana State Library during the STEM Girls in Government Camp in Fall 2019. *Photo credit: Suzi Taylor*

DIVERSITY

A primary focus for diversity in Year 2 of the project was the continued development of the CREWS Native Research Network (NRN).

The Montana Girls STEM Collaborative was selected for a national program funded by Mattel and Mercedes-Benz to combat gender stereotypes in toys.

Through NRN, three Tribal College seed grant proposals, submitted by LBHC and SKC, were funded. The UM Indigenous Research and STEM Education (IRSE) and MSU Empower programs supported native undergraduate and graduate students through courses, tutoring and mentoring, partial research assistantships, purchasing of

research supplies, and assistance with travel expenses.

IRSE and Empower also developed programs to support the participation of native middle school and undergraduate students in STEM learning opportunities. The Montana Girls STEM Collaborative, which works to inspire and include

all youth typically underserved and underrepresented in STEM, continued to expand its activities through the CREWS project in Year 2 and led efforts to feature NSF EPSCoR women as role models for young people.

The Collaborative hosted two teacher training workshops focused on youth diversity and inclusion, completed a gap analysis focused on STEM learning areas of need in Montana, and partnered with the IT Technology Managers Council in Helena to put on the STEM Girls in Government Camp, a multi-day technology experience for middle school and high school girls from rural communities.

It was also selected for a national program funded by Mattel and Mercedes-Benz to combat gender stereotypes in toys. Through this program, Montana received more than \$10,000 worth of Matchbox cars and related STEM programming to disseminate across the state, including through spectrUM Discovery Area and Missoula Food Bank, Gallatin Valley YMCA, ExplorationWorks, and Montana Afterschool Alliance.

CREWS PARTNERS AND COLLABORATORS

BROADER ENGAGEMENT

American Computer and Robotics Museum
Blackstone LaunchPad
Boys and Girls Club of Flathead Reservation and Lake County
Boys and Girls Club of Missoula County
City of Missoula Parks and Recreation
Clark Fork Watershed Education Program
Families First Learning Lab
Lewistown Boys & Girls Club
Montana Afterschool Alliance
Missoula Butterfly House and Insectarium
Missoula Food Bank & Community Center
Montana Outdoor Science School
Missoula Public Library

MSU Academic Technology and Outreach
MSU Empower
MSU Science Math Resource Center
Rosebud Conservation District
SciNation on the Flathead Reservation
spectrUM Discovery Area
UM Broader Impacts Group
UM Indigenous Research and STEM Education

RESEARCH

Clark Fork Coalition
Crow Environmental Health Steering Committee
GCS
Geum Environmental Consulting
Montana Bureau of Mines and Geology
Montana Department of Agriculture

Montana Department of Environmental Quality
Montana Fish Wildlife and Parks
Montana Natural Resources Conservation Service
Montana Natural Resource Damage Program
Montana Rural Water Systems
Missoula Department of Public Works
Montana Climate Office
Montana Institute on Ecosystems
Montana Water Center
MSU Central Agricultural Research Center
MSU Environmental Analytical Laboratory
MSU Extension
Resonon
RESPEC Consulting
Rithron Associates, Inc.

Sunburst Sensors
Trout Unlimited
UM Bird Ecology Lab
UM Environmental Biogeochemistry Laboratory
UM Flathead Lake Biological Station
University of Minnesota
University of New Mexico
US Fish and Wildlife Service
University of Vienna
US Geological Survey
Water & Environmental Technologies
Western Washington University
York College

LAND ACCESS

Thank you to the following landowners for providing access for our field work: Clark Fork Veterinary Hospital, Heggland Ranch, Ueland Ranch, Mike Morse

CREWS PROJECT LEADS

Ragan Callaway, UM, Project Director/Principal Investigator,
Maury Valett, co-PI, UM, Division of Biological Sciences & Institute on Ecosystems
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Jerry Downey, co-PI, MTU, Dept of Metallurgical and Materials Engineering
Stephanie Ewing, co-PI, MSU, Dept of Land Resources and Environmental Sciences
Venice Bayrd, MSU, CREWS Data Manager
Antony Berthelote, SKC, Dept of Hydrology
Heather Bleecker, SKC, Division of Education*
Madison Boone, MSU, Site Liaison and Communications Manager
Eric Boyd, MSU, Dept of Microbiology and Immunology*
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John Dore, MSU, Dept of Land Resources and Environmental Sciences*
John Doyle, LBHC, Crow Water Quality Project
Margaret Eggers, MSU, Center for Biofilm Engineering
Erika Espinosa-Ortiz, MSU, Center for Biofilm Engineering*
Erik Grumstrup, MSU, Dept of Chemistry and Biochemistry
Julia Haggerty, MSU, Dept of Earth Sciences & Institute on Ecosystems
Katie Hailer, MTU, Dept of Chemistry and Geochemistry*
Bob Hall, UM, Division of Biological Sciences & Flathead Lake Biological Station
Andrew Hauer, Technical Coordinator, UM

Jessie Herbert-Meny, UM, spectrUM Discovery Area
Trevor Irons, MTU, Dept of Geophysics*
Todd Kipfer, Associate Project Director, MSU
Janene Lichtenberg, SKC, Dept of Wildlife and Fisheries
Liddi Meredith, MTU, Montana Bureau of Mines and Geology
Elizabeth Metcalf, UM, College of Forestry and Conservation
Jakki Mohr, UM, College of Business
Robert Payn, MSU, Dept of Land Resources and Environmental Sciences & Institute on Ecosystems
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Jack Skinner, MTU, Dept of Mechanical Engineering
Brian St. Clair, MTU, Dept. of Chemistry and Geochemistry
Rhonda Stoddard, Fiscal Administrator, UM

Neva Tall Bear, LBHC, Science Instructor*
Suzi Taylor, MSU, Science Math Resource Center
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