BUREAU OF RECLAMATION

# R&D Office Research Updates

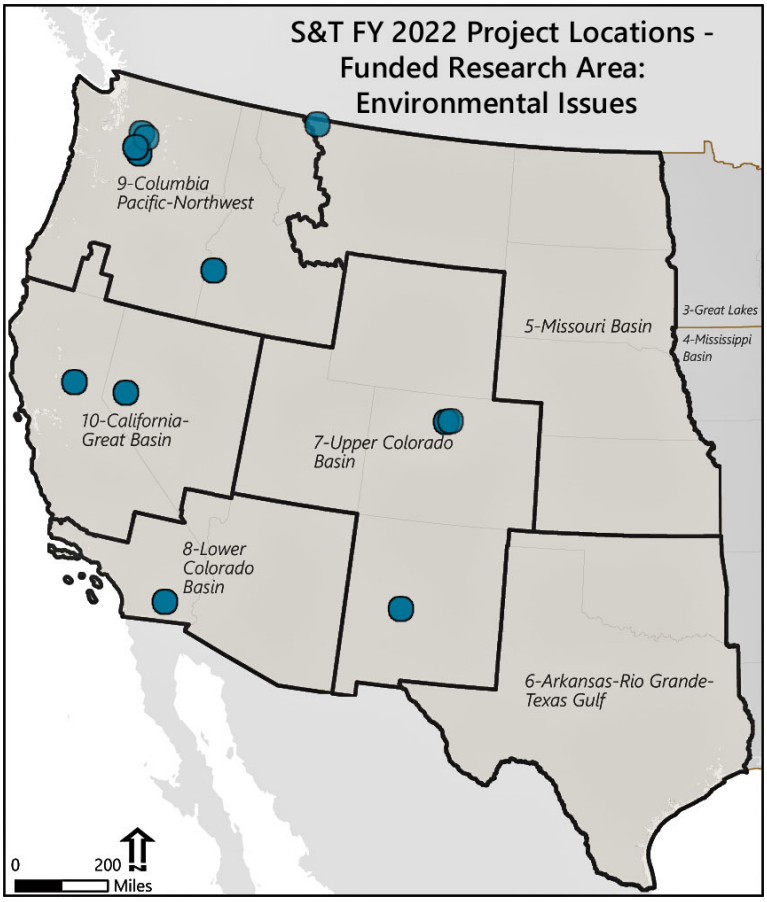
## Environmental Issues for Water Management and Delivery

U.S. Department of the Interior

January 2022

# Executive Summary

The Environmental Issues in Water Management and Delivery (EN) Research Area of the Science and Technology Program (S&T) examines research in the following categories: Water Delivery Reliability, Invasive Species, Water Quality, Sediment Management, and River Habitat Restoration. In FY22, S&T funded 39 EN Projects approximately totaling $2.1M: 11 were new totaling $1.0M and 28 were continuing totaling $1.1M. A Benefit Cost Ratio computation (BCR) was estimated for one EN project to demonstrate the value of this research. A BCR of 11.0 was calculated for the Development of a Platform for Wildfire Incident Support and Evaluation of Post-fire Impacts. The analysis recognizes that there are numerous areas where economic benefits might be realized, but focuses on the time and labor savings of fire coordination during a typical fire season with this new GIS platform. As demonstrated, EN research is extremely valuable to Reclamation, both by development of new methods and techniques, as well as by learning about technologies that should not be adopted by Reclamation Program to assist with environmental compliance.




Reclamation's Research and Development Office (R&D) manages the Science and Technology Program (S&T) and is focused on providing innovative solutions for Reclamation water and power facility managers and its western customers and stakeholders, primarily through competitive funding opportunities to Reclamation employees.

The S&T Program has five research areas (listed below) directly related to Reclamation's mission. For more information, visit: www.usbr.gov/research/st/needs_priorities/index.html.

## S&T Research Areas and Categories

### Water Infrastructure (WI)
Dams, Canals, Pipelines, and Miscellaneous Water Infrastructure

### Power and Energy (PE)
Hydro Powerplants, Energy Efficiency, Pumping Plants, and Non-Hydropower Renewable

### Developing Water Supplies (WS)
Advanced Water Treatment, Groundwater Supplies, Agricultural and Municipal Water Supplies, and System Water Losses

### Environmental Issues in Water Delivery and Management (EN)
Water Delivery Reliability, Invasive Species, Water Quality, Sediment Management, and River Habitat Restoration

### Water Operations (WP)
Water Supply and Streamflow Forecasting, Water Operations Models and Decision Support Systems, Open Data, and Climate Change and Variability

*Front cover: Red Bluff Diversion Dam, California..*

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# Environmental Issues for Water Delivery and Management

## FY21 Completed Projects

### 19080: Aging Reservoirs, Climate, Operations, and Potential Cumulative Impacts to Water Quality, Clarity and Fisheries and Recreation - Mike Horn

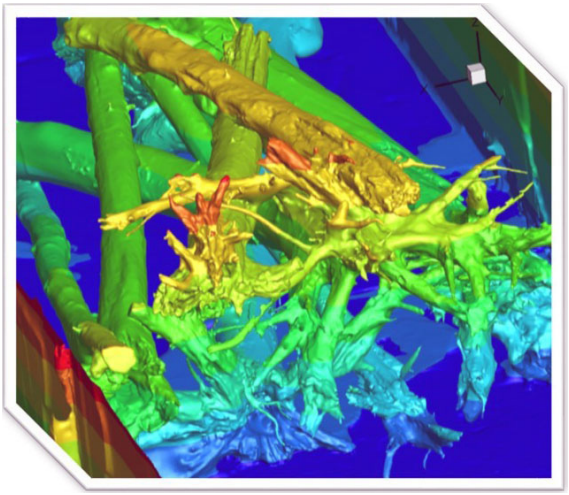
*Picture of Clark Canyon Reservoir showing large algae mats that break down and contribute to turbidity.*

In 2015 and 2016 Clark Canyon Reservoir in southwestern Montana started releasing turbid water into the downstream Beaverhead River. While in of itself the releases were not a water quality issue, the high levels of turbidity did cause a negative impact to an economically important trout fishery in the Beaver Head River downstream of Clark Canyon Reservoir. Reclamation partnered with the State of Montana to undertake a study to try and understand why these events might be occurring. Initially it was hypothesized that as the reservoir has aged there might have been a build-up of sediment that was now being released. Analysis of turbid water showed the material being resuspended was autochthonous in nature and a mixture of diatom frustules and precipitants formed in the reservoir. During 2017 and 2018 Reclamation collected daily water quality profiles at a series of points around the reservoir in addition to deploying an acoustic doppler profiler just upstream of the dam. The State of Montana maintained surface and bottom deployed data sondes that continuously collected data at a site near the dam, and midway up the reservoir. Montana also installed and maintained a meteorological station on an island in the middle of the reservoir. Analysis of these data sets combined with the results of a CE-QUAL model for the reservoir indicate turbidity episodes are primarily a function of reservoir elevation, season, and wind events. When the reservoir is full, wind events cannot break down stratification. As reservoir levels decrease stratification weakens due to continued low level releases, and the reservoir also becomes more prone to the impacts of wind events. The study found wind events generated a circulation pattern in the reservoir that can resuspend flocculent bottom material and transport it to the outflow of the reservoir where it is released downstream.

*Live pen experiment at Shag Slough, San Francisco Bay-Delta, CA, to evaluate distance and conditions at which environmental DNA from fish species can be detected.*

### 19225: Quantifying Fish Biomass X Distance from Environmental DNA Samples in a Hydrodynamically Complex Environment - Brian Mahardja

A modeling tool to analyze quantitative Polymerase Chain Reaction data from environmental DNA studies, “artemis,” was developed as a package for the R statistical programming language. To demonstrate its utility, Artemis models were fit to data from two field experiments in a tidal environment (Shag Slough, San Francisco Bay-Delta, CA): Experiment 1) 54 live Delta Smelt placed in a live pen and Experiment 2) 25 Delta Smelt and 15 steelhead placed in a live pen. Water samples were taken prior to live pen deployment in both experiments, providing control samples that represented zero target fish in Shag Slough (this was confirmed by zero detections of Delta Smelt or steelhead DNA in the control samples). Estimated eDNA concentration declined with distance of the sampling point from the live pen. Furthermore, DNA concentration in samples increased with increasing Delta Smelt-biomass level. The tool developed in this project, artemis, is effective for designing an eDNA study and analyzing the results: once a site has been characterized, artemis can be used to select the number of samples to be taken and the distribution of those samples through time to achieve a desired probability of DNA detection.



*Mesh representation of a large wood structure by the CFD model.*

## 1734: Robust Eco-Hydraulic 3D Modeling Tools for Rivers with Complex In-Stream Structures - Yong Lai

A new surface embedding method (SEM) is developed and implemented into a 3D computational fluid dynamics (CFD) model U2RANS. The modeling procedure is proposed so that 3D CFD modeling of flows through complex instream structures may be carried out for eco-hydraulic projects. All components of a CFD package to perform the CFD modeling are described. The new capability is described and verified using selected benchmark cases. In specific, a turbulent flow around a cylinder near scoured bed is used to validate the model. Good results are obtained. Further, a complex flow through a six-piece ELJ is used to demonstrate that the model works well even for complex flows. The ELJ case is further lab-tested by collaborators at the U.S. Army Corp of Engineers. The experimental data are further used to validate the model with good comparisons.

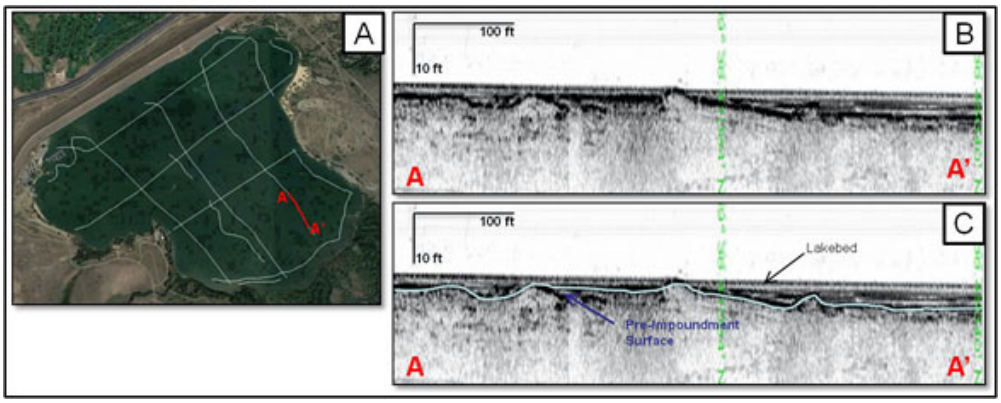
## 21046: Reservoir Delta Morphology and Effects on Tributary Fish Passage and Habitat – A Scoping Study - Colin Byrne

Fish passage limitations have been identified in several reservoir deltas and rivers throughout Reclamation's Regions. In the Yakima River Basin in Washington, delta dynamics have prevented or impaired Endangered Species Act (ESA)-listed bull trout and other salmonids from migrating between the reservoirs and upstream spawning habitat. This scoping study aimed to better understand the research needs associated with reservoir delta fish passage. The main goal of the scoping study was to develop a conducting proposal to submit in June of 2021 for fiscal years 2022 through 2024. The scoping study outcomes included a literature review, an investigation of available datasets, and the conducting proposal submission.

*Box Canyon Creek, a tributary of Kachess Lake, is one of several reservoir tributaries in the Yakima Basin with impaired delta fish passage in dry years (photo credit: Richard Visser).*

## 20067: Evaluating Chirp Technology for Measuring Reservoir Sedimentation Thickness and Stratigraphy - Daniel Dombroski

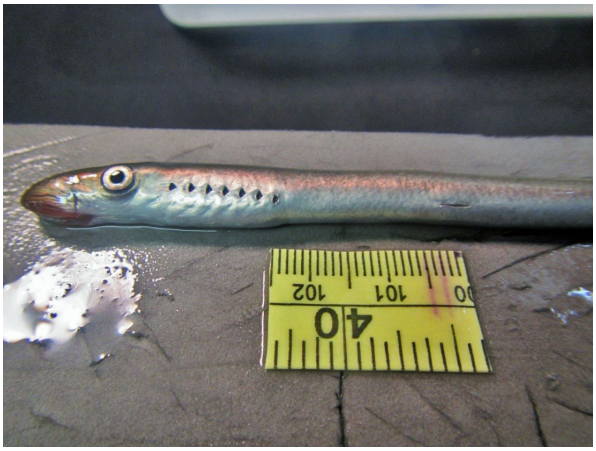
The spatial distribution, volume, and relative grain size of sediment in reservoirs influences management plans through the operational lifespan and decommissioning stage of impounding dams. Reservoir sediment studies are infrequently conducted and historical data are lacking, however—leading to great uncertainty over how to manage infrastructure. Even if bathymetric surveys have been performed (often they have not) to estimate storage capacity, little may be known about the sediment characteristics. In August 2020, USACE and Reclamation jointly used a shallow acoustic chirp system to map the stratigraphy and pre-impoundment surface of two reservoirs in Colorado. Both reservoirs are rich with complementary data regarding the distribution of sediments and pre-impoundment surface, which provides for convenient assessment of chirp system capabilities. Qualitative comparisons suggest that the mapped sub-bottom surface elevations (from the chirp system) were consistent with known pre-impoundment surfaces prior to dam construction. Approximate volumes of accumulated sediment were calculated based on the mapping effort, and observations of the reflective surface were indicative of a gently sloping alluvial plane cut by numerous shallow fluvial channels. Overall, the results were useful in demonstrating the capability of the shallow acoustic technique in imaging pre-impoundment surfaces and assessing geomorphic conditions. This project was completed with successful collaboration with Heidi Wadman from USACE.




*(A) Map view of Cherry Creek Reservoir, with approximate sub-bottom track lines plotted in white, (B) Example of un-interpreted and (C) interpreted sub-bottom profiles.*

## 19112: Monitoring the Movements of Juvenile Pacific Lamprey in the Yakima River using Acoustic Telemetry - Patrick Monk

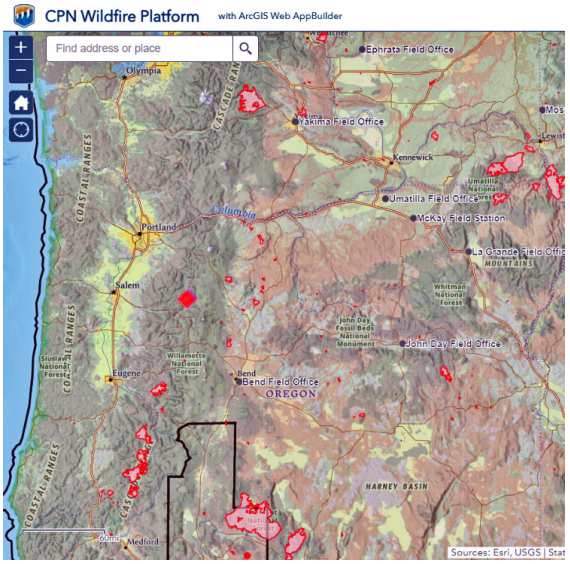
Lamprey are an important migratory fish species that move between freshwater and the ocean. Describing the seaward migration of juvenile lamprey was not possible until the recent development of an acoustic micro-transmitter for use specifically in juvenile lamprey and eels. Through a collaborative research approach, we evaluated these prototype transmitters by tagging and monitoring juvenile lamprey in the Yakima River from 2018-2021. We tagged and released 249 juvenile lamprey during the study and monitored their movements using acoustic telemetry receivers. Most tagged lamprey did not initiate downstream movements within the 18 days of tag life and overall detections of tagged lamprey were low, ranging from 25-50%. Lamprey arrived at detections sites predominantly during periods of darkness (85.3 to 96.6 percent). Travel rates through the study area ranged from 0.2 to 45.3 km/d, and lamprey generally remained at each detection station for less than about 20 minutes. The prototype tags functioned properly but lamprey migratory behavior was unpredictable and short battery life limited our ability to monitor lamprey movements. Research to extend lamprey transmitter battery life is ongoing.



*A juvenile Pacific Lamprey is being tagged with an acoustic transmitter.*

## 20019: Development of a platform for wildfire incident support and evaluation of post-fire impacts - Kendra Fallon

The CPN Wildland Fire Platform (App) has shifted fire management in the CPN Region from reactive to proactive by overlaying near-real time fire perimeters, new starts, and current wildland fire locations and spread direction with mapped CPN lands and assets. This provides a window of opportunity to communicate threats of existing or new wildland fires that may impact Reclamation assets or mission work to Reclamation personnel and relay concerns to the suppression resources for tactical and planning considerations during the management of the incident. The app is available to all Reclamation employees to "self-serve" information regarding incidents at any time instead of relying on communication or response from the CPN Wildland Fire Coordinator.




*Screen capture of the CPN Wildland Fire App with selected open-source fire and Reclamation layers displayed. The app can be found at https://usbr.maps.arcgis.com/apps/webappviewer/index.html*

## 21200: Modeling of Rivers in the Hydraulics Laboratory - Melissa Shinbein

Distorted scale physical modeling is an effective means of modeling long stretches of rivers where depths would be too shallow if scaled using an undistorted scale. A distorted scale model uses a different horizontal and vertical scale compared to the prototype. The ratio of horizontal to vertical scaling is known as the distortion ratio. Distorted scale physical models are not frequently used by the Bureau of Reclamation's Hydraulics Laboratory due to the types of model studies typically requested in support of Reclamation's mission. Previous distorted scale models at Reclamation's Hydraulics Laboratory have used a distortion ratio of less than 5 in order to collect quantitative and qualitative model data. Distorted scale models have been used more frequently by the U.S. Army Corps of Engineers (USACE) and other laboratories in academia with distortion ratios of over 20. This study includes a literature review of distorted scale modeling used by other laboratories, the laboratory techniques employed for data collection, and the usability of the results produced at the distorted scale. Results of this scoping study show that distorted scale modeling at distortion ratios up to 10 may be feasible in Reclamation's Hydraulics Laboratory for physical models of rivers with larger spatial extents in future studies.

*Example of distorted physical model scaled to a distortion ratio of 2 and successfully provided velocity data for fish passage in urban flood control channels.*

# FY22 New Projects

### 22008: The use of a multi-sensory behavioral barrier as a fish deterrent to reduce entrainment at the St. Mary Diversion Dam, Milk River Project, Montana - Lauri Teig

The purpose of this project is to evaluate a multi-sensory barrier would span 58-feet across the total width of the headgates to reduce entrainment of bull trout.

### 22015: Nuisance Aquatic Vegetation (NAV) Control in Water Delivery Systems: An Automated Metering System for Accurate and Consistent Herbicide Application - Kevin Kelly

This project proposes four major goals – developing a modern version of a previously patented automated metering system, testing of the modernized prototype in laboratory and field trials, measurements of important metrics such as cost savings, and field trial demonstrations to a wider audience including Reclamation stakeholders.

### 22019: Potential impacts of phosphorous loading from wildfire-fighting retardants related to the East Troublesome fire on surface water quality in Willow Creek and Willow Creek Reservoir - Lindsay Bearup

This project will evaluate the fate and transport of phosphorous post-wildfire in the Willow Creek drainage and Willow Creek Reservoir through water quality and sediment sampling.

### 22025: Leveraging the results of an invasive saltcedar leaf beetle impact monitoring study to create a risk assessment and restoration prioritization tool on the Middle Rio Grande, NM - Kristen Dillon

This project will integrate the results of ongoing Diorhabda impact assessment research, 25 years of Southwestern Willow Flycatcher (SWFL) population monitoring, and detailed habitat maps to develop an actionable tool that can be used to prevent SWFL population decline, rather than taking less effective and more costly reactionary steps to recover the population after severe loss has already occurred.

### 22065: Investigating the physical processes that impact reservoir delta fish passage and evaluating potential solutions - Colin Byrne

Two main research objectives are proposed to address fish passage problems on reservoir deltas: 1) develop a conceptual understanding of geomorphic processes of reservoir delta evolution focusing on how channel flow depth, sedimentation patterns, and inundation dynamics impact fish passage, and 2) use the conceptual model to formulate and evaluate solutions that promote sustainable fish passage across reservoir deltas.

### 22066: Recent Advances in Selenium Treatment Technologies, Application to Emerging Wetlands, and Pilot Project Implementation Plan in the Salton Sea, California - Angel Gutierrez

Given the projected growth of playa wetlands around the Sea and potential selenium hazards to fish and wildlife using them, this effort can help Reclamation and its partners plan for Se risk reduction as the region evolves.

### 22067: Evaluation of Shallow Acoustic Sub-Bottom Profiling Technologies for Measuring Reservoir Sedimentation Thickness and Stratigraphy – Englebright Lake, California - Dan Dombroski

The proposed study will determine the effectiveness of different sub-bottom profiling instruments in characterizing deposited sediments and determining pre-impoundment surfaces at a reservoir with well-studied geomorphic conditions. Chirp systems utilize high-powered acoustic pulses over a range of relatively low frequencies to penetrate up to tens of meters into sediments for remote characterization of stratigraphy.

### 22070: Scoping Project for Salton Sea Windblown Playa Dust Modeling - Angel Gutierrez

This scoping proposal will allow the team to further develop the approach and methodology for the modeling project and seek partnerships from other agencies and stakeholders at the Sea.

### 22077: Enhancing Reclamation's Watershed Model to Predict Post-Fire Sediment Delivery to Reservoirs and Assess Management Actions -Benjamin Abban

An interagency team proposes to extend SRH-W's capability to include wildfire impact prediction and evaluation of related management efforts. Project goals are to incorporate wildfire-related physical processes (land cover/soil property changes) into SRH-W by adopting state-of-the-art research; and to validate and demonstrate the benefits of the enhanced SRH-W model in the Willow and North Inlet Creek watersheds, CO, recently affected by the East Troublesome wildfire.

## FY22 New Projects *-continued*

### 22088: Evaluation of Mercury Release from Sediment and Dredging to Lahontan Reservoir Waters - Dan Deeds

The potential impact of mercury release during dredging is of high concern and this study proposes the collection of sediment cores from Lahontan Reservoir and benchtop experiments evaluating the possible extent of mercury release from excavated reservoir sediment.

### 22097: Evaluating watershed response and increases in sediment loading to Willow Creek and Willow Creek Reservoir due to East Troublesome fire – Kent Collins

Monitoring sediment deposition in the Willow Creek Reservoir over multiple years is needed to determine and possibly predict the watershed and reservoir response to large-scale wildfires.

## FY22 Active Projects

| ID | Final Year | Title | Lead |
|---|---|---|---|
| 1792 | 2022 | Using beryllium-10 derived erosion rates as a proxy for reservoir sedimentation | Melissa Foster |
| 1809 | 2022 | Mercury Loading to Streams and Reservoirs: A Process-Based Approach | Yong Lai |
| 8101 | 2022 | Measuring Gravel Bar Mobility in Large Rivers with Tracer Gravel | Nate Bradley |
| 19105 | 2022 | Fish Passage at River Diversion Juncture: A Science-Based Approach | Yong Lai |
| 19266 | 2022 | Side channel evolution and design: achieving sustainable habitat for aquatic species recovery | Nathan Holste |
| 19290 | 2022 | Improving predictions of scour in the vicinity of vegetation in habitat rehabilitation areas | Daniel Dombrowski |
| 19306 | 2022 | Side channel evolution, geomorphic diversity, and sediment transport on the Bighorn River following larger dam releases between 2008 and 2018 | Melissa Foster |
| 20031 | 2022 | The potential for restoring thermal refuges in rivers for cold-water salmonids | Aaron Hurst |
| 20042 | 2022 | Threat Assessment and Evaluation of Burrowing Crayfish in Reclamation Canals | Aaron Murphy |
| 20045 | 2022 | A Methodology for Rockwad Velocity and Predator Habitat | Jenna Paul |
| 20052 | 2022 | Quantifying the Development and Dynamics of Reservoir Delta and Related Backwater Vegetation in the Context of Physical Drivers | Nathan Holste |
| 20057 | 2022 | Modeling effects of wildfire and fire retardant on nutrients downstream in a watershed scale | Jun Wang & Dan Deeds |
| 20060 | 2022 | River restoration interactive geospatial database to inform future river rehabilitation design | Melissa Shinbein |
| 20064 | 2023 | Monitoring Detritus Deposition and Scour Downstream of Minidoka Dam with Implications to Snake River Physa Snail Habitat and Irrigation Canals. | Daniel Dombrowski |
| 20069 | 2022 | Monitoring Suspended Sediment: An Investigation Coincident with the Cherry Creek Reservoir Annual Flush | Daniel Dombrowski |
| 20091 | 2022 | Determining the capabilities and limitations of Unmanned Aircraft Systems (UAS) equipped with Light Detection Ranging (LiDAR) sensors when applied to hydrologic studies, infrastructure, mapping, and general land data collection | Meyer Jay |
| 20094 | 2022 | Cyanophage treatment development for mitigating freshwater Harmful Algal Blooms caused by cyanobacteria | Christopher Waechter |
| 21008 | 2022 | Resolving Spatiotemporal Distribution of Suspended Sediment Concentration over the Columbia and Snake River Using Remote Sensing | Kendra Fallon |
| 21013 | 2022 | Sediment effects on river restoration habitat features: physical processes and guidelines for effective and sustainable design, planning, and maintenance | Meghan Thiemann |
| 21015 | 2023 | Physical and Surrogate Data Collection of Sediment Transport in Ephemeral Systems | David Varyu |
| 21016 | 2023 | Laboratory and Field Testing of Enzyme and Microbially Induced Carbonate Precipitation for Mitigation of Fugitive Dust at the Salton Sea | Angel Gutierrez |

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## FY22 Active Projects *-continued*

| ID | Final Year | Title | Lead |
|---|---|---|---|
| 21054 | 2023 | Abrasivity of Slurry-Transported Sediment: Development of a Laboratory-Based Test System | Evan Lindenbach |
| 21075 | 2023 | Modeling Riverine Pool Temperature Stratification and Reservoir Selective Withdrawal for Fish Spawning and Rearing Habitat | Yong Lai |
| 21077 | 2023 | Predicting Reservoir Drawdown Flushing to Improve Reservoir Sustainability | Victor Huang |
| 21078 | 2022 | Chemical Fingerprinting of Delta Smelt for Sensitive Detection in the Environment | Daniel Deeds |
| 21084 | 2022 | Cost Estimating Guidelines for Dam Decommissioning Alternative | Jennifer Bountry |
| 21088 | 2023 | Sediment effects on river restoration habitat features: physical processes and guidelines for effective and sustainable design, planning, and maintenance | Drew Baird |
| 21092 | 2023 | Utilizing Hydrophones to Detect Streambed Mobilization in the Wild and Scenic Reach of the Rio Chama | Rebecca Braz |
| 22008 | 2023 | The use of a multi-sensory behavioral barrier as a fish deterrent to reduce entrainment at the St. Mary Diversion Dam, Milk River Project, Montana | Lauri Teig |
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