BUREAU OF RECLAMATION

Research Updates R&D Office

Environmental Issues for Water Management and Delivery

U.S. Department of the Interior

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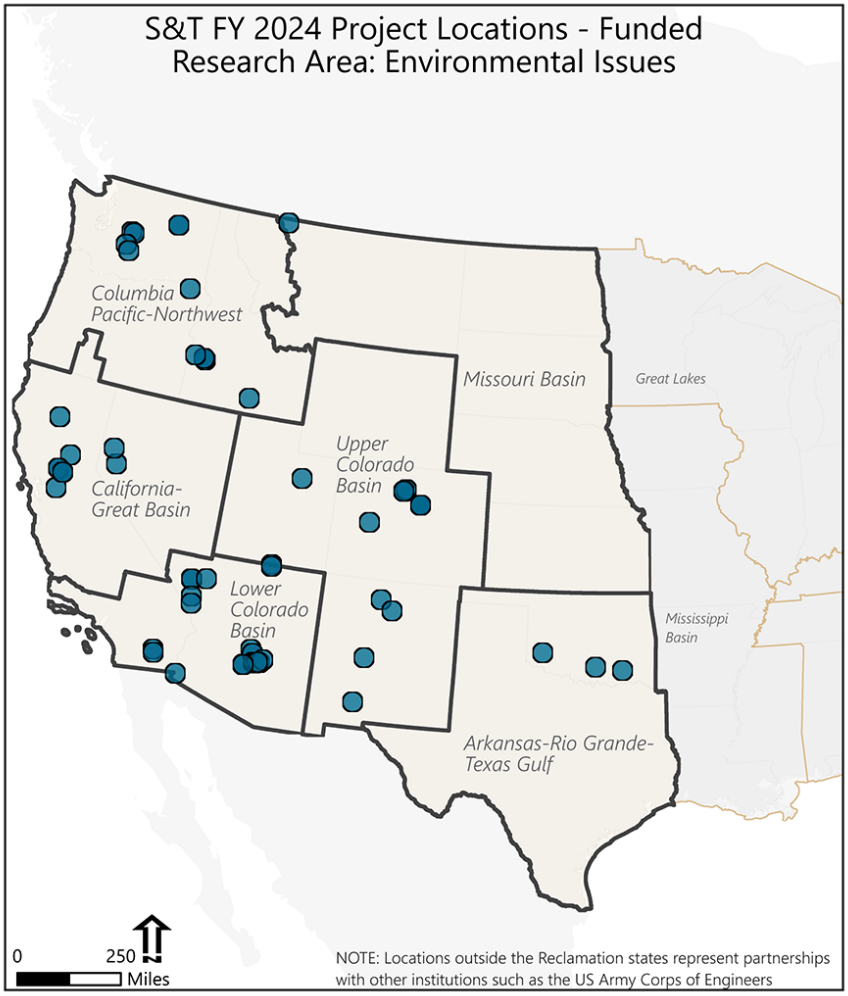
Executive Summary

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 FY24, S&T funded 39 EN Projects approximately totaling $1.5M: 5 were new totaling $0.4M and 34 were continuing totaling $1.1M. Additionally, the new Facilitated Adoption program funded one EN project as part of its inaugural funding cycle ($0.14M). EN research is extremely valuable to Reclamation, both by development of new methods and techniques, as well as by learning about technologies that could be adopted by Reclamation Programs 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

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Environmental Issues for Water Delivery and Management

FY23 Completed Projects

20069: Monitoring Suspended Sediment: An Investigation Coincident with the Cherry Creek Reservoir Annual Flush – Daniel Dombroski

From 2017-2022, USACE, USGS, and Bureau of Reclamation (Reclamation) crews collected hydraulic and sediment data to test the capabilities and limitations of the LISST-ABS sensor, designed for suspended sediment monitoring using acoustic backscatter as a surrogate for suspended sediment concentration. The exercises were conducted during an annual reservoir flushing exercise at Cherry Creek Dam near Denver, Colorado. The instrument offers several compelling advantages, including low cost, ease of use, portability, and capability for long-term autonomous deployment. The results of the study are useful in addressing questions such as:

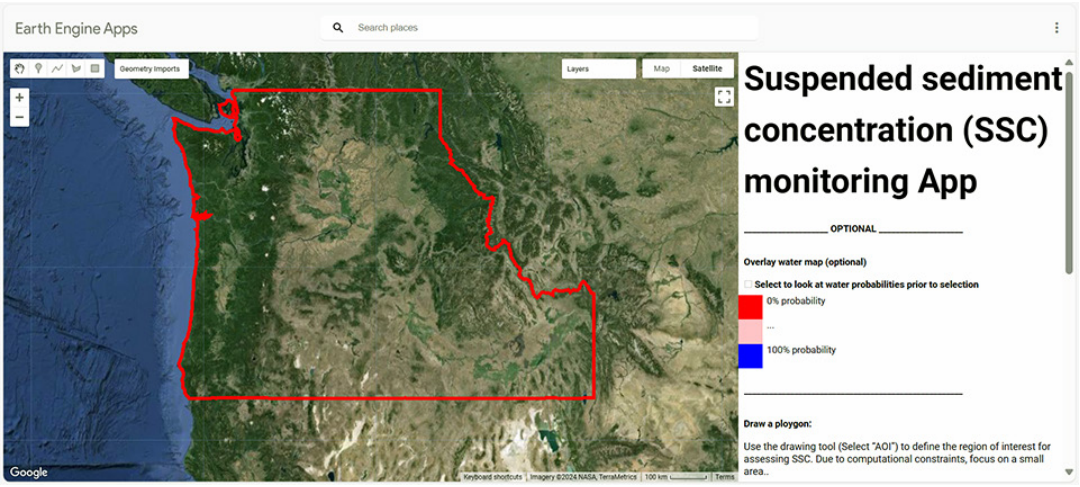
- Do modern sediment monitoring techniques using the LISST-ABS instrument offer a feasible and cost-effective solution to meeting Reclamation's needs in addressing sediment management issues in reservoirs and rivers?
- Can continuous approaches to monitoring sediment using surrogate methods provide the resolution and depth of data necessary to guide reservoir flushing exercises and inform computational models with implications to reservoir sustainability?
- What best practices should users adhere to for ensuring consistent and robust data collected using the LISST-ABS instrument?

Terrain elevation ranges of the Upper Cache Creek overlaid on a hillshade of the sub-watershed modeled in the study.

The investigation revealed challenges associated with making stable and reliable measurements; however, these drawbacks can largely be overcome through setup of a thoughtful deployment scheme and assimilation of laboratory calibration routines. The project implementation benefited greatly from collaboration between USACE, USGS, and Reclamation engineers and technicians, which resulted in a mutually beneficial study through shared planning and resources.

21008: Resolving Spatiotemporal Distribution of Suspended Sediment Concentration Over the Columbia and Snake River Using Remote Sensing – Michael J. Poulos

Ground measurements of suspended sediment concentrations are expensive, and lack the temporal and spatial resolution and coverage required for informed water-related decisions. This project leveraged cloud computing with Google Earth Engine and Harmonized satellite imagery from Landsat and Sentinel 2 satellites to develop a remote sensing-based model for monitoring of suspended sediment concentrations over all water bodies in the Pacific Northwest between 1984-present. The underlying Random Forest model uses reflectance in VIS, NIR and SWIR bands to estimate suspended sediment concentrations, and achieves a coefficient of determination of 0.76 over the test data. Findings implied that limits-of-predictability might have been reached with the available data, i.e., more complex models may not markedly improve the modeling accuracy. This is attributed to several factors, including (1) the temporal lag/lead between satellite and ground observation used for training might implicate model performance, (2) preprocessing algorithms for satellite imagery might implicate water reflectance, (3) spectral mixing and bed reflectance might implicate water reflectance. Future projects may focus on synchronized ground observations at the time of satellite overpass, or fusion of coordinated airborne, ground, and satellite observations.



North Western US Suspended sediment concentration (earthengine.app)

19290: Improving Predictions of Scour in the Vicinity of Vegetation in Habitat Rehabilitation Areas – Daniel Dombroski

Looking at potential restoration area along Middle Rio Grande, New Mexico. (Photo Credit James Fluke)

A modeling suite has been developed for simulating vegetation lifecycle and the effects on hydraulics and sediment transport in the riparian environment. The models are based upon the SRH-2D package (Lai, 2010), which contains a two-dimensional flow and mobile bed sediment transport model.

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With combined support from Reclamation's Science & Technology Program and the Albuquerque Area Office, the cumulative stress lifecycle model was applied to analyze revegetation alternative actions associated with a channel realignment project along a subreach of the Rio Grande in New Mexico. We analyzed the response of four species to three annual hydrographs that represent wet, average, and dry conditions. Relationships between hydrology, hydraulics, groundwater, and vegetation are complex, and the modeling provides useful insights by parameterizing variables and linking important physical processes. As originally scoped, the focus of the proposed study was to improve ability to predict scour in and around vegetated areas, utilizing the realignment project as a numerical case study. Updates to the vegetation model will be necessary in order to include the capabilities within a public-facing distribution of the SRH-2D modeling suite. We project these updates to be conducted under the umbrella of facilitated adoption and plan to propose support through Reclamation's Research Office during fiscal year 2024.

20052: Quantifying the Development and Dynamics of Reservoir Delta and Related Backwater Vegetation in the Context of Physical Drivers – Nathan Holste

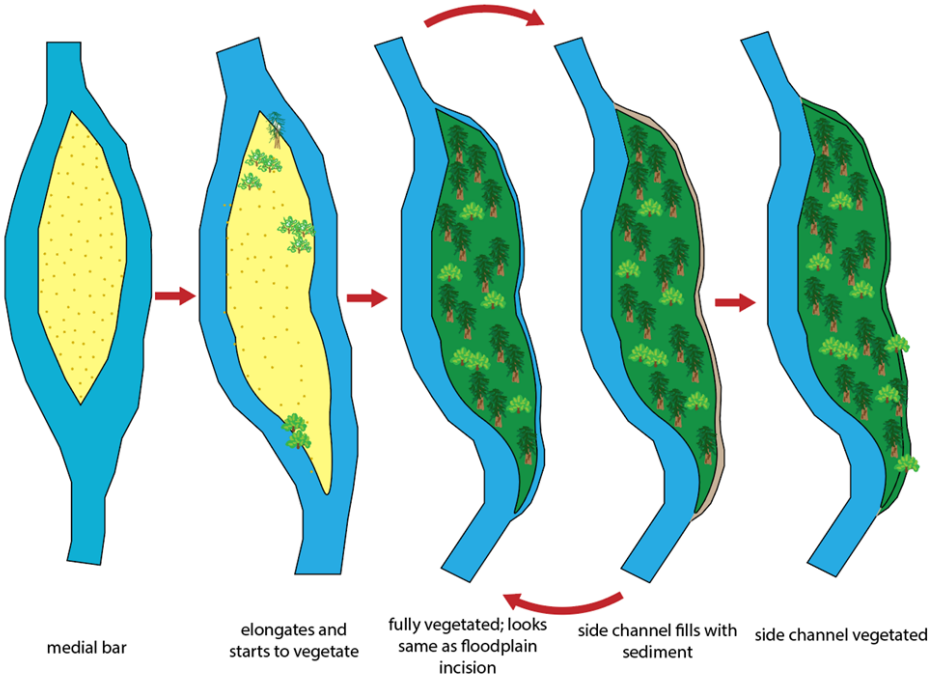
This investigation focused on large-scale vegetation patterns related to the physical formation of delta-backwater landforms and their dynamic response to fluctuations in reservoir pool elevations. The study includes detailed analyses at Fort Peck Lake and Lake Powell along with an initial characterization of Lake Mead and Elephant Butte Reservoir. Hybrid plant communities have established, expanding available habitat at the reservoirs we examined. Some of this new habitat appears to be of high quality with an abundance of native species, whereas other reservoirs appear to support primarily non-native species. At Fort Peck Lake, development of the delta-backwater across the wide Missouri River bottomland was accompanied by a progressive increase in mesic riparian cover with little comparative change in cover types upstream of the reservoir backwater influence. Supervised classification indicated that the mesic cover type was dominated by early successional willows, cottonwoods, and herbaceous wetland species. At Lake Powell, continued sediment deposition in the upper reaches of the reservoir created new surfaces that were rapidly colonized and dominated by the early successional, non-native tamarisk. Following a drop in pool elevation during the early 2000s, the Colorado River incised the accumulated sediment, creating terraces. Vegetation on these widespread, hydrologically disconnected terraces is now subject to seasonal stress and mortality. The different physical and biological responses between these two reservoirs result from several interacting factors, including regional climate, valley slope and confinement, as well as the frequency, magnitude, and duration of reservoir fluctuations.

Elephant Butte Reservoir delta with emergent vegetation and wetlands becoming established on recent sediment deposits. (Reclamation/Nathan Holste)

19266: Side Channel Evolution and Design: Achieving Sustainable Habitat for Aquatic Species Recovery – Nathan Holste

Side channels increase the hydraulic and geomorphic complexity of river systems, which provides aquatic habitat by reducing velocity and increasing shoreline length and cover. Constructed side channels are a common habitat restoration technique to improve ecological value, but design guidance is limited. This study analyzed naturally formed side channels to improve the efficacy of constructed projects. We used historical aerial imagery of the Middle Rio Grande, the Sacramento River, and the Trinity River to better understand how side channels form, how they evolve, and how long they persist. We identified and classified side channels between 1935 and 2012 with a time series of at least five different years for each river. Classification types consider if the side channel was likely created by erosion or deposition through processes such as lateral channel migration or channel avulsion. Evaluating spatial and temporal trends for each river highlights relationships between geomorphic processes and side channel abundance and longevity. The Middle Rio Grande is the most dynamic river system and has many side channels that alternate between types. For example, bars can become accreted and then re-incised to join the main channel multiple times throughout a side-channel's history. The Trinity River has almost no change between side channel types, which suggests that less mobile rivers will have more stable and longer-lasting side channels.

Side channel on the Middle Rio Grande during high flow snowmelt runoff. (Photo credit Reclamation/Robert Padilla)



Side channel evolution process showing a medial bar in the channel that elongates and becomes vegetated. Through time the side channel can accrete to the bank of the main channel and fill in with sediment before becoming vegetated and abandoned.

21084: Cost Estimating Guidelines for Dam Decommissioning Alternative – Jennifer Bountry

As dams age, structural and operational maintenance investments increase until a time when decisions on whether to rehabilitate, replace, or decommission the dam need to be made. Decommissioning a dam may be considered when the purpose of the dam is no longer needed or other factors such as dam safety, lost storage due to sedimentation, fish passage, recreation safety, or river restoration goals take higher priority and are more economically feasible for the dam owner long-term. Dam safety, river restoration, and asset class management programs need cost estimating methods to consider dam decommissioning when appropriate.

Major Cost Drivers (surrogate indicators)	Yes	No
Will more advanced construction methods be required? (e.g. coffer dam for dewatering, cranes for tall dams, helicopters for remote access)		
Is sediment volume large relative to the river's sediment load? (e.g. many years average annual sediment load, reservoir width >> river width, phased removal)		
Will the reservoir or dam be missed? (e.g. infrastructure replacement, navigation use, lake recreation, expected litigation, stakeholder outreach, societal value, historical landmark)		
Will there be extensive remedial actions? (e.g. revegetation, restoration, grade control,...)		
Is there "reason to believe" complexities will increase cost? (e.g. sediment quality, archeological sites, buried infrastructure,...)		

Total number of "Yes" answers

0 1 2 3 4 5

$ Range of potential dam removal costs $$$$

Scoping questions developed to provide early identification of potential cost drivers associated with dam removal cost analysis.

This joint effort with USGS, USACE, and Oregon State produced four planning-level tools for dam decommissioning: (1) new databases of case studies; (2) scoping questions to help determine if complexity cost drivers will be present; (3) machine learning based regression trees to estimate a potential cost range; and (4) a Computation Guide for Cost Estimating that can be used to inform discussions on potential dam removal cost items, quantities, and unit costs.

Looking upstream at Savage Rapids Dam removal in Oregon during construction. (Photo credit Jennifer Bountry)

Using the collected data and knowing some basic characteristics about the average annual flow and geographic location of the dam site, in addition to dam size, can improve the ability to use past case studies for planning-level cost estimating. By additionally analyzing the likelihood of complexity cost drivers such as sedimentation management, difficult access, or replacement infrastructure needed, the initial uncertainty of a cost estimate can be further reduced.

FY24 New Projects

Evaluation of an Upstream Bank Stabilization and Sediment Removal Project on Fish Passage for Threatened and Endangered Species at Marble Bluff Dam on the Lower Truckee River Above Pyramid Lake – Carolyn Gombert

The Marble Bluff reservoir on the Truckee River has completely filled with sediment, impeding upstream passage of fish including the threatened Lahontan cutthroat trout and endangered Cui-ui sucker. These species are very important to the Pyramid Lake Paiute Tribe, a project partner. Reclamation is planning a sediment removal and bank stabilization project upstream of Marble Bluff Dam, which will include a new channel flow path. This study will monitor fish movement through the dam and the reach upstream before and after implementation of this project. Results will illustrate the impact of sediment management on endangered and threatened species.

Developing an In-stream Sr Isoscape for California's Central Valley to Determine Migration Patterns of Anadromous Fish – Grace Windler

California's Central Valley waterways – the Sacramento-San Joaquin River system – are home to several fish species listed under the Endangered Species Act, including steelhead trout, green sturgeon, and four distinct runs of Chinook salmon. Managing these species is a challenge, as the large geographic extent and the complex water infrastructure make it difficult to track population dynamics and rearing habitats. Linking the strontium (Sr) isotope composition of fish otoliths (calcium carbonate 'ear stones') to Sr isotope variation across a river system is a powerful tool for identifying habitats and migration paths, but it is limited by the spatial extent and accuracy of existing data. In collaboration with researchers at the University of California Davis, the University of California Santa Cruz, and the National Oceanic and Atmospheric Administration, this project will leverage existing Sr isotope data and collect additional Sr isotope samples to improve spatial coverage and capture seasonal variability.

Identification of Kokanee and Burbot Spawning Habitats in Lake Roosevelt Using Environmental DNA and RNA – Yale Passamaneck

The kokanee (Oncorhynchus nerka), a sockeye salmon that lives its entire life in freshwater, and the native burbot (Lota lota) fish species are culturally and spiritually important to Native Americans in the Columbia River Basin. However, their population levels are impacted by operations at Grand Coulee Dam. Population management for both species is limited by a lack of information regarding spawning locations and recruitment success. A more effective method of identifying spawning grounds is key to their conservation and management. This project aims to use environmental DNA (eDNA) and environmental RNA (eRNA) to identify spawning locations in Lake Roosevelt, the Columbia River, and its tributaries. Environmental RNA (eRNA) will be used to gain a more detailed insight into the timing and location of spawning.

Creating Effective Monitoring and Response Guidance for Addressing Surface and Benthic Algal Blooms within Reclamation's California-Great Basin Region – Laura Benninger

Harmful Algae Blooms (HABs) have become an increasing concern for water managers as they threaten municipal drinking water, wildlife habitat and impair human recreational opportunities. Expanding upon an S&T report, "Reclamation Harmful Algal Bloom Impacts and Research Needs", this scoping project will conduct an extensive literature review to produce (a) a summary of research concerning the physical, chemical, and temporal factors that promote and impede acute and chronic HAB occurrences and (b) a report summarizing HAB monitoring methods and instrumentation, including information about instrument costs and availability. In coordination with the California State Water Board, a Reclamation-specific guidance document/standard operating procedure for HAB monitoring and response will be developed for Reclamation's California-Great Basin region.

FY24 New Projects *-continued*

Reservoir Sedimentation Management: Evaluation of Nature-based Solutions for Distributed Sediment Detention and Storage in Water Supply Watersheds – Ben Abban

This study aims to evaluate the degree to which watershed-scale sediment management practices can address reservoir sedimentation issues, with emphasis on the performance of in channel controls. We will use a combination of field studies and numerical watershed models developed by Reclamation to characterize structures that imitate natural systems, including beaver mimicry structures and rock detention structures. Specifically, we will study the beneficial impact of watershed-scale restoration provided by wetlands and beaver ponds within the channel network on sediment delivery. Our focus will be on the Paonia Reservoir (Colorado) watershed, given its well-known sedimentation issues and the availability of sediment flux data. The outcome will be the capability to inform watershed-wide sediment reduction strategies that are environmentally friendly, cost-effective, and efficient for Reclamation's reservoir sediment management.

FY24 New Facilitated Adoption Projects

FA24072: Gather and Transfer Facilitated Adoption – Yong Lai

Stakeholders exploring the feasibility of anadromous fish passage and reintroduction in the upper Columbia River are seeking a reduction in Life Cycle Modeling uncertainty. This project focuses on testing critical uncertainties associated with reservoir and downstream passage survival, such as site-specific migration and passage survival data. The resulting survival estimates generated from this study will guide decision making regarding the need for, and location of, juvenile fish passage facilities at Chief Joseph Dam and Grand Coulee Dam. This project builds off of a completed Prize Competition, "Divide and Conquer."

FY24 Active Projects

ID	Final Year	Title	Lead
1792	2024	Using Beryllium-10 Derived Erosion Rates as a Proxy for Reservoir Sedimentation	Melissa Foster
19105	2024	Fish Passage at River Diversion Juncture: A Science-Based Approach	Yong Lai
19306	2024	Side Channel Evolution, Geomorphic Diversity, and Sediment Transport on the Bighorn River Following Larger Dam Releases Between 2008 and 2018	Melissa Foster
20031	2024	The Potential for Restoring Thermal Refuges in Rivers for Cold-water Salmonids	Aaron Hurst
20042	2024	Threat Assessment and Evaluation of Burrowing Crayfish in Reclamation Canals	Scott O'Meara
20057	2024	Modeling Effects of Wildfire and Fire Retardant on Nutrients Downstream in a Watershed Scale and Lake B Wildfire Support	Jun Wang
20060	2024	River Restoration Interactive Geospatial Database to Inform Future River Rehabilitation Design	Melissa Shinbein
22015	2024	Nuisance Aquatic Vegetation (NAV) Control in Water Delivery Systems: An Automated Metering System for Accurate and Consistent Herbicide Application	Kevin Kelly
21015	2024	Physical and Surrogate Data Collection of Sediment Transport in Ephemeral Systems	David Varyu
21054	2024	Abrasivity of Slurry-Transported Sediment: Development of a Laboratory-Based Test System	Evan Lindenbach
21075	2024	Modeling Riverine Pool Temperature Stratification and Reservoir Selective Withdrawal for Fish Spawning and Rearing Habitat	Yong Lai
21077	2024	Predicting Reservoir Drawdown Flushing to Improve Reservoir Sustainability	Victor Huang
21078	2024	Chemical Fingerprinting of Delta Smelt for Sensitive Detection in the Environment	Daniel Deeds
21088	2024	Sediment Effects on River Restoration Habitat Features: Physical Processes and Guidelines for Effective and Sustainable Design, Planning, and Maintenance	Drew Baird
22008	2024	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
22067	2024	Evaluation of Shallow Acoustic Sub-Bottom Profiling Technologies for Measuring Reservoir Sedimentation Thickness and Stratigraphy – Englebright Lake, California	Daniel Dombroski
22066	2024	Recent Advances in Selenium Treatment Technologies, Application to Emerging Wetlands, and Pilot Project Implementation Plan in the Salton Sea, California	Matthew Alinsod
20091	2024	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
21008	2024	Resolving Spatiotemporal Distribution of Suspended Sediment Concentration Over the Columbia and Snake River Using Remote Sensing	Michael Poulos
21016	2024	Laboratory and Field Testing of Enzyme and Microbially Induced Carbonate Precipitation for Mitigation of Fugitive Dust at the Salton Sea	Angel Gutierrez
21092	2024	Utilizing Hydrophones to Detect Streambed Mobilization in the Wild and Scenic Reach of the Rio Chama	Rebecca Braz

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FY24 Active Projects *-continued*

ID	Final Year	Title	Lead
22019	2024	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
22065	2024	Investigating the Physical Processes that Impact Reservoir Delta Fish Passage and Evaluating Potential solutions	Colin Byrne
22077	2024	Enhancing Reclamation's Watershed Model to Predict Post-Fire Sediment Delivery to Reservoirs and Assess Management Actions.	Benjamin Abban
22088	2024	Evaluation of Mercury Release from Sediment and Dredging to Lahontan Reservoir Waters	Grace Windler
22097	2024	Evaluating Watershed Response and Increases in Sediment Loading to Willow Creek and Willow Creek Reservoir Due to East Troublesome Fire	Kent Collins
23025	2024	Quantification of Accuracy Improvements Related to Multibeam Data Processing.	David Varyu
23039	2024	Boulder Cluster Design Guidance for River Restoration	Melissa Shinbein
24025	2024	Creating Effective Monitoring and Response Guidance for Addressing Surface and Benthic Algal Blooms within Reclamation's California Great Basin Region	Laura Benninger
20064	2025	Monitoring Detritus Deposition and Scour Downstream of Minidoka Dam with Implications to Snake River Physa Snail Habitat and Irrigation Canals.	Daniel Dombroski
23015	2025	Reintroduction of Anadromous Fish to the Blocked Areas of the Upper Columbia River. Downstream Movement and Survival of Juvenile Salmon in the Upper Columbia River Basin	Sue Camp
23021	2025	Large Wood Representation in a Two-Dimensional Hydraulic Model	Yong Lai
23026	2025	Tracing Salinity through the Southern Sacramento-San Joaquin River Delta, California Using Continuous Salinity Monitoring, High-speed Salinity Transects, and Ion Fingerprinting	Grace Windler
20045	2026	A Methodology for Rockwad Velocity and Predator Habitat	Jenna Paul
23022	2026	Food for Fish: A 2-Dimensional Fate and Transport Model for Zooplankton with Implications for Juvenile Salmon Growth and Water Management Efficiency	Jenna Paul
24009	2026	Evaluation of Upstream Bank Stabilization and Sediment Removal Project on Fish Passage for Threatened and Endangered Species at Marble Bluff Dam on Lower Truckee River Above Pyramid Lake	Carolyn Gombert
24013	2026	Developing an In-stream Sr Isoscape for California's Central Valley to Determine Migration Patterns of Anadromous Fish	Grace Windler
24019	2026	Identification of Kokanee and Burbot Spawning Habitats in Lake Roosevelt Using Environmental DNA and RNA.	Yale Passamaneck
24055	2026	Reservoir Sedimentation Management: Evaluation of Nature-based Solutions for Distributed Sediment Detention and Storage in Water Supply Watersheds	Benjamin Abban
FA24072	2026	Gather and Transfer (Follow-up to "Divide and Conquer" Prize Competition)	Yong Lai