Climate change and land use are significantly reshaping interactions among vegetation, soils, subsurface and fluvial compartments of watersheds throughout the world. While watersheds are recognized as Earth's key functional unit for assessing and managing water resources, hydrological processes in watersheds mediate most, if not all, biogeochemical processes that support terrestrial life. Despite the importance of watershed function to agriculture, energy, urban and other societally important systems, the scientific community is at a preliminary stage of developing a predictive understanding of how watersheds function from a hydrological and biogeochemical perspective, and how they will respond to increasingly frequent perturbations, such as floods and droughts.

The Genomes-to-Watersheds SFA (FY14-FY16) undertook what may have been the first coordinated attempt to gain a predictive understanding of metabolic potential of a terrestrial environment in the context of system-wide fluxes and a range of heterogeneity. Working within the Rifle floodplain of the Colorado River, our experimental and observational efforts transformed what we now know about the subsurface microbiome and their metabolic potential for mediating a wide range of biogeochemical cycles. We documented the role of the vadose zone in carbon cycling at the site, and used geophysical approaches to quantify hot spots in the floodplain that influenced biogeochemical cycling. We developed the first ever genome-enabled biogeochemical watershed simulation capability (GEWaSC), challenged it with diverse field data, and successfully documented the improvement in predictions of biogeochemical cycles and exports to the Colorado River enabled by inclusion of genomic information.

We are now building upon our genome-enabled floodplain advances to predict watershed function and dynamics. In this move to greater scales and complexity, we take a 'system-of-systems' view of the watershed. Recognizing that while it is typically impossible to perform explicit characterization and modeling of a watershed everywhere at high resolution (in the manner previously performed at Rifle, CO), we adopt a scale-adaptive construct that assumes that the integrated watershed response to disturbances (such as floods, droughts and earlier snowmelt) can be adequately predicted through consideration of a limited number of subsystems within the greater watershed system, where the collection of chosen subsystems are assumed to exhibit a range of residence times and reaction rates relevant to water, nutrient, carbon and metals processing within the watershed.

The Watershed Function SFA (FY17-FY19) proposes to develop and test the ability of scale-adaptive approaches to address an **overarching science question of 'how will mountainous watersheds retain and release water, nutrients, carbon and metals downgradient?' In particular, the SFA will quantify how warming, early snowmelt and hydrological perturbations will influence mountainous watershed dynamics that impact downstream water availability and biogeochemical cycling at seasonal to decadal timescales.** We propose to initiate this project in a headwater catchment of the Upper Colorado River Basin, perhaps the most important basin in the Western U.S., which supplies municipal water to more than 1 in 10 Americans, irrigation water and nutrients to more than 5.5 million acres of land, and supports more than 4,200 megawatts of electrical generating capacity, and supports diverse ecosystems that provide other societally relevant services.Four theme-based hypotheses have been identified to address the SFA question of how mountainous watersheds retain and release water, nutrients, carbon, and metals downgradient:

- **Hydrology:** Decreased snow cover and earlier snow melt due to warming of mountainous watersheds will reduce overland flow and increase early season infiltration, leading to deeper transport of solutes and increased production of CO_2 within the vadose zone
- **Ecohydrology:** Feedbacks between hydrology-driven changes in vegetation and vegetation-driven changes in hydrology will increase evaporative loss and decouple microbially-mediated biogeochemical processes that control nutrient fluxes in mountainous watersheds
- **OrganoMineral Dynamics**: The intensity of hydrological pulses to floodplain sediments and the hydrologic residence time within shale materials will control the release of carbon, nitrogen, and metals to riverine systems
- **Watershed Reactor**: Hydrologic perturbations to mountainous watersheds lead to nonlinear riverine fluxes of water, carbon, nutrients and metals, which can be predicted using a scale-adaptive framework that takes into account variable residence time versus reactivity relationships associated with subsystems.

This poster will highlight advances made during the past year as part of the Genomes-to-Watershed SFA, and will describe recent research to develop the next Watershed Function SFA and associated scale-adaptive approaches.