Eel River Critical Zone Observatory

Year 3 Annual Report
June 2016

Table of Contents

A. Accomplishments 2
B. Products 11
C. Participants 12
D. Impact 13
E. Changes/Problems 18
F. Special Reporting Requirements 19

A. Accomplishments

1. What are the major goals of the project?

The major goals of the Eel River CZO as outlined in our Management plan are to answer these four questions:

1. Does lithology control rock moisture availability to plants and therefore overall resilience of vegetation to climate change in seasonally dry environments?
2. How are solute and gas effluents from hillslopes influenced by biota in changing moisture regimes?
3. What controls the spatial extent of wetted channels in the channel networks of seasonally dry environments?
4. Will changes in critical zone currencies induced by climate or land use change lead to threshold-type switches in river and coastal ecosystems?

Additionally, we propose to develop a numerical platform – the Atmosphere-Watershed-Ecology-Stream and-Ocean Model (AWESOM) to synthesize findings from smaller scale studies, couple the different critical zone subsystems together, and explore the long-term and large-scale consequences of the dynamics of the critical zone in the context of changes in climate, land use, and water management policy.

2. What was accomplished under these goals?

a. Major activities:

Question 1: Does lithology control rock moisture availability to plants and therefore overall resilience of vegetation to climate change in seasonally dry environments?

In this reporting period, the major activities driven by Question 1 were: 1) establishment of a monitoring system in the critical zone developed on the mélange, 2) installation of a vadose zone monitoring system, and 3) monitor rock moisture and tree sap-flow and water-potential.

<u>1) Establishment of a monitoring system in the mélange critical zone (Sagehorn Ranch)</u>

During this reporting period we established a new monitoring site in the mélange bedrock, 20 km to the east of our intensive monitoring site (Sagehorn Ranch). The site is located on the privately-owned Sagehorn ranch. We picked two watersheds (Dry, 3.4 km^2 and Hank (5.8 km^2), entirely in mélange and within the ranch, to focus our monitoring. On the ridgeline separating the two east-west oriented watersheds we have line-of-sight access to our radio tower at Cahto Peak in the headwaters of Elder Creek (within which our Rivendell site lies). Hence, we have a series of south and north facing hillslopes and a ridgeline that allows us to connect our instrumentation to our remote download system and view the date online, virtually in real time.

By July 1, 2015 we established a meteorological station (rain, wind, PAR, relative humidity, solar radiation and barometric pressure). In August 2015, a team from Wyoming Center for Environmental Hydrology and Geophysics assisted by ERCZO students, faculty and staff conducted shallow seismic and electrical resistivity surveys along 4 lines (two running across the central ridge from Dry to Hank Creek; one running along the ridge and one running parallel to the ridge but half-way down towards the channel). The longest line was about 900 m long. Total line length was in excess of 2 km. In late September, we conducted a drilling campaign that established 10 wells ranging from 1.8 m to 18 m deep along the ridgeline.

We also established a water level recorder on both Dry and Hank and through winter measurements of runoff developed a rating curve for each watershed. Rain and snow water were collected for stable isotope and chemical analysis. So far we have collected about 56 well water, 57 rain, and 23 of stream flow samples. In addition we have collected over 87 samples of bulk drilled-materials for stable isotope analysis.

In May 2016 we conducted a ground survey of woody vegetation on the north and south hillslopes that included a large sandstone block covered by a dense forest. In the mélange, sandstone blocks of sufficient size commonly support denser forests, and offer an opportunity to compare local lithologic controls on vegetation. More than 2000 individual trees were documented over a 10 hectare area.

<u>2) Installation of a vadose zone monitoring system at Rivendell</u>

In late October 2015, we installed a vadose zone monitoring system (VMS) at the Rivendell site. It involved drilling parallel to the relatively planar hillslope (along contour) two 19 m long holes at a 55 degree angle relative the horizontal. Sleeves were then lowered down each hole. On sleeve "A" are ten TDT (Time Domain Transmissometry) devices (distributed at nearly even intervals (to a vertical depth of 16m)) to measure rock moisture dynamics. These instruments also measure temperature. Pressure at each of the 10 levels is measured via ports connected to a control panel above ground level. At each interval, 0.25 cm long silica pillows serve as lysimeters to collect water. On sleeve "B", installed approximately 1 m upslope, there are ten 1.5 m long sampling ports (which drain to silica pillows) designed to capture more freely draining water likely traveling through fractures. Near these ports are nine gas sampling ports in which tubing perforated along 1.25 m sections is used to extract gas.

Since installation of the VMS, water samples have been collected 13 times. Water samples were split into separate containers for anion, cation, and stable isotope analysis. The cation and anion samples (as well as rainwater samples) are delivered to Assistant Professor Jennifer Druhan at the University of Illinois Urbana Champaign (UIUC) for analysis. Over 46 samples have been analyzed. Dr. Druhan's group also analyzed material samples (weathered and fresh bedrock) collected during drilling. In addition, UIUC has analyzed anion and cation concentrations of Elder Creek and surrounding stream samples as well as bulk digestions of solid phase recovered from well cores for Well 10.

<u>3) Monitor rock moisture and tree sap-flow and water-potential</u>

Periodic neutron probe surveys to document rock moisture dynamics were continued throughout the sampling period at Rivendell and initiated at Sagehorn. At Rivendell and Sagehorn we instrumented trees for water use by installing sapflow sensors and piston dendrometers (as well as spring-band dendrometers to document long-term growth). At Rivendell we instrumented 4 trees each on north and south facing slopes. At Sagehorn we instrumented 3 trees each on the north and south facing slopes. More than 250 individual shoot water potential measurements were made using a pressure chamber at Rivendell and Sagehorn. One tree at Rivendell was installed with a psychrometer to measure xylem water potential for a two-week period.

Question 2: How are solute and gas effluents from hillslopes influenced by biota in changing moisture regimes?

During this reporting period, we focused on: 1) monitoring O_2 and CO_2 gas profiles in wells at Rivendell, and 2) collecting and analyzing soil samples for genomic characterization. At approximately monthly intervals, O_2 and CO_2 profiles were documented in wells at Rivendell. In addition, in one well a continuous monitoring of O_2 and CO_2 at two depths below the surface (1.5 and 3 m) was completed over about a 70 day period in late summer and early fall.

Six samples of soil from forested Rivendell and 70 samples collected from a grassy meadow formed on river alluvium were subject to metagenoimc analysis to compare the microbial communities in these different settings. Samples were also collected to investigate the saprolite rhizosphere community with emphasis on interactions between the trees, fungi, bacteria, and archaea. Three replicate Douglas Fir rhizosphere from the saprolite and corresponding bulk, 3 non-rhizosphere soil samples were collected and sent to JGI for metgaenomics analysis. We have assembled 200 giga base pairs of sequence data, and have binned 11 near complete bacterial and archaeal genomes and three complete fungal mitochondria and three bacterial phages, with many more to come. Samples for microbial analysis were also collected along the two VMS drill holes.

Question 3: What controls the spatial extent of wetted channels in the channel networks of seasonally dry environments?

We surveyed the early (May) and late summer (August) wetted channel extent of the Hank and Dry Creek watersheds in 2015. These are the two monitored watersheds located in Sagehorn Ranch in the Central Belt mélange.

We developed multiple stochastic hydrologic models for seasonally dry watersheds and identified issues with ubiquitous methods for streamflow recession analysis.

Question 4: Will changes in critical zone currencies induced by climate or land use change lead to threshold-type switches in river and coastal ecosystems?

During the review period, many field studies were carried out to link stream flow and temperature (both mediated by discharge from the critical zone) to food webs, salmon survival, invasive species, and the growth of harmful cyanobacteria. The persistence of the warm California drought offered a valuable opportunity to document key stresses on the system.

These field campaigns and modeling were conducted in this reporting period:

1) Twenty-four transects at paired tributary and mainstem surveys along the South Fork and mainstem Eel were surveyed for algae and cyanobacterial status, insect abundance, and fish densities.

2) Deployment of cyanotoxin samplers along the mainstem and Middle Fork of the Eel. Samples were also collected of benthic macroinvertebrates living within cyanobacterial (*Phormidium*) mats to see if these insects concentrate the bacteria. During a three-week period nutrients were added to streamflow to determine response by cyanobacteria. Twenty-two samples of *Phormidium* mats were collected for metagenomic analysis.

3) Snorkel surveys in the South Fork were done to document if salmon use of cold-water refugia. Observations were made to see if the infection by a parasite on the salmon was more common in warmer water. Distribution of an invasive species (pikeminnow) was mapped to document if they preferred the warmer waters. A numerical model was developed to explore the pattern of cold water where cold waters of tributaries enter the warm water of the mainstem.

4) Measurements of fish growth were done to determine if late summer low, food poor conditions influence growth rates.

5) We explored the role of magnitude and timing of rain, and the barriers resulting from waterfalls on the timing of salmon out-migration and the decision to remain as resident fish.

AWESOM : The Atmosphere-Watershed-Ecology-Stream and-Ocean Model

Focus this year has been on extending our hydrologic model that accounts for fracture flow and predicts rock moisture dynamics to include the role of root water extraction.

b. Specific Objectives

Milestone 1. Does lithology control rock moisture availability to plants and therefore overall resilience of vegetation to climate change in seasonally dry environments?
1.1 Continue automated monitoring system at Rivendell
1.2 Continue monitoring of rock moisture dynamics by performing repeat neutron probe surveys in deep wells at the Rivendell field site
1.3 Collect samples for stable isotope measurements for identifying the role of ectomychorizae on tree water use in rock
1.4 Continue to collect and analyze sap flow and tree psychrometer data on North and South Rivendell
1.5 Install Vadose Zone Monitoring System at Rivendell field site
1.6 Comparative analysis of LiDAR data for Angelo and Sagehorn Ranch
1.7 Develop monitoring network on melange study site (Sagehorn Ranch)
1.8 Create a geospatial database of geological, biogeochemistry and hydraulic conductivity for Angelo and mélange site (Sagehorn Ranch)

Milestone 2: How are solute and gas effluents from hillslopes influenced by biota in changing moisture regimes?
2.1 Document the phylogenetic and functional profile of vadose zone microbial communities
2.2 Document the phylogenetic and functional profile of the Douglas fir rhizosphere
2.3 Investigate seasonal changes in microbial populations and influence on atmospherically reactive trace gasses
2.4 Analyze chemistry of rainwater and of groundwater samples and streamflow collected by ISCO samplers at Rivendell
2.5 Monitor CO2 and O2 profiles in wells Rivendell

Milestone 3: What controls the spatial extent of wetted channels in the channel networks of seasonally dry environments?
3.1 Conduct two wetted channel surveys in two watersheds on melange landscape (Sagehorn ranch)
3.2 Establish a rating curves multiple channels in Eel River CZO
3.3 Continue streamflow recession analyses

Milestone 4: Will changes in critical zone currencies induced by climate or land use change lead to threshold-type switches in river and coastal ecosystems?

4.1 Conduct experiments to investigate the effects of nutrients, light, and temperature on the growth of cyanobacterial mats

4.2 Collect cyanobacterial samples for genetic analysis to understand the dispersal patterns of cyanobacterial mats
4.3 Continue to track fish using stationary antennae
4.4 Conduct fish surveys and classify abundance by pool
4.5 Compile synoptic food web surveys linked to environmental regimes of temperature, light, and flow regimes
4.6 Explore spatial and temporal variation in temperature with flow in confluences and pools

Milestone 5: Synthesis Modeling (the Atmosphere-Watershed-Ecology- Stream-Ocean Model)
5.1 Continue hillslope hydrologic model refinement, including root-rock interactions and lateral flow
5.2 Advance theory for diurnal stream flow oscillations

c. Significant results: (Numbers correspond with 'Specific objectives' above)

1.1 Ongoing—no significant results to report.

1.2 Analysis of neutron probe, streamflow and groundwater data suggest that rock moisture storage in the unsaturated zone likely controls the timing of wet season streamflows: 1) after 'critical' (annually repeatable) storage is achieved, precipitation transits through the unsaturated zone to the groundwater which runs off to the channel throughout the year; 2) spatial structure of weathering influences timing of recharge and rock moisture storage: permeability contrasts resulting from weathering restricts fluctuation of groundwater table to narrow zone (i.e. once water table is elevated to a high permeability zone, it transits laterally rapidly). This permeability structure generates rapid runoff (ensuring much of the precipitation will runoff during wet season) and limits the amount of seasonal groundwater that can be stored for summer baseflow; and 3) a 'critical' rock moisture storage is achieved annually, even in drought year and is depleted slower than soil throughout the summer (i.e. we're starting the 2016 summer, with the same amount of storage as the previous two years, which had very different seasonal rainfall).

1.3 Samples for stable isotope measurements for identifying the role of ectomychorizae on tree water use in rock have been collected.

1.4 We expanded this objective to include a north- south comparison at the Sagehorn mélange site. We showed that at the end of the summer, trees living in the mélange (garry oaks) were pulling much harder and the subsurface had a much lower water potential than trees living at Rivendell.

1.5. Initial data from stable isotope analysis of the VMS shows that the distinct isotopic signatures of individual storm events is lost due to mixing of successive storms waters in the upper 8m of the vadose zone, where temperatures and moisture content fluctuate seasonally. VMS moisture content monitoring shows direct evidence of preferential flow and diffuse wetting. Even at 14 m, matrix continually increases in moisture content as storms pulse through. Initial results also demonstrate that major cation ratios of the VMS fluids and groundwater fall between silicate and carbonate endmembers, and vary substantially along this mixing line over monthly timescales. Redox sensitive constituents such as sulfate, iron and manganese all demonstrate substantial concentration increase in samples collected across the lowest depths of the VMS, where the system is periodically saturated.

1.6 The channel network density is nearly twice as high on the Sagehorn Ranch mélange (Coastal Belt) rocks compared to the Angelo Coast Range Coastal Belt (argillite, sandstone, conglomerates). This corresponds to the common occurrence of saturation overland flow extending to close to the drainage divide in the mélange.

1.7 The weather station we installed at Sagehorn shows that the rainfall there is about 85% of that measured in Rivendell, confirming the similar rainfall regime. The depth to the water table in mélange is relatively shallow (compared to Rivendell), even at the end of summer and at the end of a drought on the ridge, saturated material was encountered ~2 m from ground surface in mélange matrix. This material is unoxidized (fresh or 'blue), consistent with perennial saturation, indicating a shallow depth to fresh bedrock. This past winter we documented that most of the Sagehorn landscape generates saturation overland flow during major storm events. Correspondingly, for the same storm event, runoff was faster and much larger at Sagehorn compared to Rivendell

1.8 Data base is being developed.

2.1 Surprising amount of overlap exists between samples collected from soil in the forested Rivendell site and from the nearby meadow. 749 microbial species (out of 5602) were found in all samples.

2.2 Analysis ongoing—no significant results to report.

2.3 Analysis ongoing—no significant results to report.

2.4 No significant results to report this period.

2.5 Simultaneous measurement of CO_2 and O_2 show: 1) strong diurnal oscillations in both gasses, 2) in some wells CO_2 and O_2 are inversely related.

3.1 The wetted channel extent of the Hank Creek and Dry Creek watersheds were surveyed the early and late summer 2015. These watersheds are located on Sagehorn Ranch in the Central Belt Melange geologic region. The wetted channel drainage density (WDD) of Hank Creek and Dry Creek, were 1.3 and 1.0 km/km^2 respectively in the early summer. By the late summer Hank and Dry dried out dramatically, decreasing to WDDs of 0.13 and 0.15 km/km^2, respectively. This equates to a 6-9-fold decrease in WDD. The Fox Creek (2.7 km^2) and Elder Creek (17.0 km^2) watersheds at the Angelo Reserve, geologically underlain by Coastal Belt (but only 20 km NE of Sagehorn Ranch), experience similar climate, but receive 15% more precipitation than Sagehorn Ranch. The WDD of Fox Creek and Elder Creek watersheds decreased by only 25% over the summer months. The Central Belt (Hank and Dry) watersheds dried out at a rate at least 25 times the rate of the Coastal Belt watersheds (Fox and Elder), showing the influence geology has on two watersheds with very similar climates.

3.2 We focused our attention on developing rating curves for the new sites on the mélange- with great success.

3.3 Developed multiple stochastic hydrologic models for seasonally dry watersheds. Identified issues with ubiquitous methods for streamflow recession analysis.

4.1 We conducted a 3 week nutrient addition experiment to see the response of cyanobacteria to nutrient increases. However, there was no difference in the area of cyanobacterial mats among the treatments.

4.2 We collected 22 samples of Phormidium mats in August 2015. Half of the samples have been sequenced and the other half we are waiting for the sequencing data from the facility. The process of assembling and binning the genomes from these metagenomic samples has begun and analyses to look at genetic variation among samples will begin once all the genomes are assembled and binned.

4.3 We have tagged fish in Elder Creek (n = 815 in 2014, n = 921 in 2015) and Fox Creek (n = 232 in 2014, n = 158 in 2015). 96 fish have been detected with antenna at Elder. Fish tend to leave Elder Creek on the rising or falling limb of storms.

4.4 Ongoing—no significant results to report.

4.5 Ongoing—no significant results to report.

4.6. In summer 2015, we conducted preliminary snorkel surveys and found that fish make use of the areas with colder temperatures. We have also linked increased infection rates by a trematode parasite in salmonids (which causes a condition known as black spot disease) to warmer stream temperatures. An idealized fluid dynamics model that describes the cold zones at confluences in the SF Eel River performs well.

d. Key outcomes or other achievements:

Water-shed or Water-store: the importance of critical zone evolution

A key question of the Critical Zone Observatories is how the evolution of the critical zone influences hydrologic and ecologic processes. The comparison of the recently established Sagehorn monitoring site on the mélange with the Rivendell site on the argillite and sandstone has quickly revealed just how important the critical zone structure (or architecture) is. Sagehorn is a water- shedding landscape, while Rivendell is a water-storing landscape.

At Rivendell (on the Coastal Belt argillite and sandstone bedrock), our 12 wells and extensive geophysical surveys have documented an upslope thickening of the subsurface critical zone (where the bedrock is weathered) from 4m at the base of the slope to 25 m at the divide. All rainfall passes through the thin soil mantle and into saprolite and deeper fractured weathered bedrock where it collects as rock moisture or, once moisture content is sufficient high, passes along fractures to recharge the perched water table developed on the fresh bedrock boundary ($z_{b\,b}$). Runoff occurs via lateral groundwater flow to the adjacent channel. This deep storage of rock moisture supports forest transpiration and the stored groundwater slowly drains during the long dry summer thereby sustaining summer base flow (even in severe drought). The river ecosystem (including endangered salmon and frogs) (as well as people who rely of stream flow as water supply) depends on this slow groundwater discharge. Repeated field surveys of the extent of wetted channel in this region shows the stream sources to be surprisingly stable in position, likely reflecting local fracture drainage of the groundwater. The outflow at these springs progressively declines (as the groundwater is slowly drained). The critical zone structure, by dictating flow paths and travel times, also controls chemical evolution of the runoff water, and supports a deep, dynamic microbial community, emitting gasses and driving geochemical processes. The coarse structure of the critical zone here of a distinct lower boundary (z_b), that rises more slowly than the surface topography upslope towards the divide, has been found (using geophysical surveys) at 4 other nearby hillslopes. The observations are consistent with an analytical model that predicts the z_b profile as a function of channel incision rate and saturated conductivity of the fresh bedrock.

The Sagehorn site, located only about 20 km away, and receiving about 15% less rainfall, has a radically different critical zone structure developed on the melange. To our surprise, even at the end of summer we encountered fresh, saturated bedrock at about 2m from the ground surface at the hilltop (at Rivendell the depth to fresh bedrock at the divide is 25 m). The soil is about 30 cm to 80 cm thick. This past winter (our first monitoring period) after about 200 mm rain, saturation overland flow was repeatedly generated from the hilltop to adjacent channels during storm events. Simply put, the rainfall exceeded the infiltration capacity of the shallow critical zone and excess water ran off across the surface. The overland flow branched into a dense network of channels down to adjacent streams. These streams quickly responded to pulses of rain generating high peak flows, while, in contrast at the Rivendell site during the same storms, stream flow showed delayed dull peaks. We anticipate a much greater variation in solute concentration with discharge due to saturation overland flow dilution (Rivendell solutes are nearly invariant with discharge). During the summer the creeks quickly become dry and consequently there are no fish and only a seasonal aquatic ecosystem. Spring flow, not enough to sustain base flow in the channel, predominantly emanates from large sandstone blocks in the mélange. The thin critical zone which provides no groundwater storage for summer baseflow also holds only limited and relatively tightly held rock moisture in the thin weathered bedrock and soil zone. Consequently, the oaks in the mélange exert much higher water potential to sustain sap flow compared to oaks at Rivendell during the summer. The dominant vegetation here is grassland on the South facing slopes with scattered deciduous oaks. On the North slopes there is greater tree density and brush. Douglas fir (the dominant conifer at Rivendell) is only found on the sandstone blocks. The coarse structure of the critical zone here, revealed by 10 wells and 4 geophysical survey lines, appears to be influence by two different controls, which are currently under investigation. Our analytical model for the fresh bedrock profile under hillslopes suggests that relatively slow channel incision rates and very low saturated conductivity favors a thin critical zone. The hummocky surface topography of hillslopes at our field site also indicates deep disruption and downslope movement by earthflows (a signature process in the mechanically-weak mélange). Geophysical surveys also suggest deep displacement of fresh bedrock. Earthflow removal of an evolving critical zone may also inhibit the development of a thick zone.

We now see how in the same climate just differences in the tectonic history of the bedrock can lead to radically different critical zone evolution. One is zone thick, and stores and slowly releases water, thereby supporting forest and river ecosystems. The other is shallow and sheds winter rains, leaving enough moisture for grass and scattered deciduous trees, but unable to support stream flow in the summer

3. What opportunities for training and professional development has the project provided for funded personnel?

A key attribute of the ER CZO is that post-docs, graduate students and undergraduate typically work with several of our PIs whose expertise range across atmospheric science, tree physiology, geomorphology, microbial ecology, geobiology, hydrology, stream ecology and geochemistry. Geologists and atmospheric scientists work on where trees get their water, microbial ecologists study hydrologic processes and geochemistry, and stream ecologists explore the geomorphic processes that control fish distribution and foodwebs. Students freely interact across four departments, four deans and three colleges. This training will create “critical zone scientists.”

During monthly meetings attended by all ER CZO participants, both undergraduate and graduate students present their research and debate findings. These presentations fine tune their speaking skills and sharpen their research efforts. We discuss research findings, future plans and ways to connect the pieces of the critical zone. We subsidize students to attend meetings and work closely with them to prepare them for presentations and to advise them on manuscript preparation. Additionally, many of the CZO graduate students have supervised multiple undergraduates, both in the field and in the laboratory.

The graduate students are forming a group identity and have begun sharing technology and field skills. Students frequently train new students on deployment, operation and data collection from field instruments. The PIs also spend considerable time in the field with graduate students, training them in field methods and developing measurement procedures, and in the laboratory to teach analytical and modeling methods.

4. How have the results been disseminated to communities of interest?

Our CZOMP lists our strategy for engagement with other CZOs – which focused on common questions and measurements and cross-site research. We proposed that several strategies to engage the larger community including publishing papers, presenting findings at meetings, sharing data, and welcoming participation by groups not affiliated with the CZO network.

Engagement by the research community is growing. We have expanded our collaborations with University of California, Davis (Houlton) on nitrogen in bedrock; Penn State (Brantley) on microporsity in the weathering zone, Wyoming (Holbrook) on structure of the critical zone, Northwestern/UC Riverside (Packman/ Aronson) on microbiology, Wuhan University (Dedi Liu) on hydrologic modeling, Wright State (Vadeboncoeur) on toxic algae blooms, UC Berkeley Visiting Scholar Kupferberg on amphibian conservation, University of Illinois (Druhan) on solute evolution (and reactive transport modeling) through the critical zone; Institut de Physique du Globe de Paris (Bouchez and Gaillardet) on isotope fingerprints of groundwater; Oregon State University (Pett-Ridge) on river molybdenum isotope concentrations; University of Alberta (Oliver- a CZO SAVI funded proposal) on carbon and nutrient exports from the Eel River: Universite de Rennes (Bormans) on cyanobacteria.

5. Goals during next reporting period

As specified in the CZO reporting guidelines our goals are presented as a graphical timeline.

	2016							2017								
	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept
Task 1																
Monitor vadose zone moisture dynamics	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Conduct tree survey at two field sites	■	■	■	■	■						■	■	■	■	■	■
Evaluate water potential in trees with pressure chambers and psychometers			■	■	■	■			■	■	■					
Continue instrumentaion of trees with force sensors	■	■	■	■	■							■	■	■	■	■
Develop and parameterize numerical model of root forces, and bedrock-to-soil to conversion						■	■	■	■	■	■	■	■	■	■	■
Task 2																
Continue microbial genome analysis from sequenced soil	■	■	■	■	■	■										
Begin analysis of mircrobial genomes of populations in weathered bedrock	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Collect soil samples for metagenomics and metatranscriptomics to link tree physiology, to microbial activity and trace gas production				■												
Collect fungal hyphae for DNA extraction and sequencing to reconstruct fungal genomes	■															
Continue periodic sampling of gas weathered bedrock	■	■	■	■	■	■	■	■	■	■						
Collect and analyze VMS samples at Rivendell, and rainfall and runoff samples from Sagehorn and Rivendell	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Task 3																
Analyze wetted channel extent for Rivendell and Sagehorn	■	■	■	■												
Develop semi-distributed hydrologic model	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Task 4																
Investigate relationships among river food webs, stream flows, and juvenile salmon	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Continue assessement of cyanotoxin bioaccumulation in macroinvertebrates and cyanobacterial dispersal dynamics	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Conduct longitudinal surveys for salmonid genetic samples	■	■	■	■	■											
Collect water temperature data using UAVs	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Continue development of idealized 3D refugia model						■	■	■	■	■	■	■	■			
Begin experimental assessment of influence of temperature on growth of California roach							■	■	■	■	■	■	■	■	■	■
Conduct repeat surveys along South Fork and mainstem Eel at tributary junctions of habitat, insects, algae, and fish abundance	■	■	■													
Task 5--AWESOM Model																
Adapt existing plant-soil-atmospheric model to Angelo/Sagehorn plant community	■	■	■													
Couple model to a saturated water module and stable isotopic analysis				■	■	■	■	■	■	■	■	■	■	■	■	■
Explore coupling 1D vadose zone and groundwater model to Community Land Model				■	■	■	■	■	■	■	■	■	■	■	■	■

B. Products

1. Publications
See attached list.

2. Technologies or Techniques
Nothing to report.

3. Inventions, Patent Applications, and Licenses
Nothing to report.

4. Websites
Nothing to report

5. Other Products
Nothing to report

C. Participants

1.

Last Name	First Name	Role	Last Name	First Name	Role
Banfield	Jill	Co-I	*(cont.)*		
Baxter	Wendy	Technician	Miller	Quinn	Undergraduate Student
Bilir	T. Eren	Graduate Student	Murphy	Colleen	Undergraduate Student
Bishop	Jim	Co-I	Nelson	Mariel	Undergraduate Student
Bode	Collin	Other Professional	Ngheim	Athena	Undergraduate Student
Bouma-Gregson	Keith	Graduate Student	Ogle	Virginia	Other Professional
Burton-Tauzer	Ryley	Undergraduate Student	Oliver	Allison	Visiting Postdoc
Cargill	Samantha	Undergraduate Student	Oshun	Jasper	Graduate Student
Carlson	Stephanie	Co-I	Pneh	Shelley	Baccalaureate
Charampoluous	Kyriakos	Undergraduate Student	Power	Mary	Co-I
Chung	Michaella	Postdoctoral	Purcell	Benjamin	Undergraduate Student
Cooperman	Weseley	Undergraduate Student	Rajendran	Meghna	Undergraduate Student
Dawson	Todd	Co-I	Rempe	Daniella	Graduate Student
Dietrich	William	PI	Rios-Dominguez	Andrea	Undergraduate Student
Dralle	David	Graduate Student	Rose	Jennifer	Technician
Feng	Xue	Postdoctoral	Rossi	Gabe	Graduate Student
Firestone	Mary	Co-I	Schaaf	Cody	Undergraduate Student
Fung	Inez	Co-I	Sharrar	Allison	Graduate Student
Georgakakos	Philip	Graduate Student	Soto	Natalie	Undergraduate Student
Greer	George	Graduate Student	Starr	Evan	Graduate Student
Hahm	W. Jesse	Graduate Student	Stein	Ilana	Graduate Student
Hauptman	Sam	Undergraduate Student	Tabibzdeh-Nuri	Arianna	Undergraduate Student
Huang	Betty	Undergraduate Student	Tao	Yujia	Undergraduate Student
Hunter	Jennifer	Other Professional	Theiss	C. Roland	Undergraduate Student
Intrator	Naomi	Graduate Student	Thompson	Sally	Co-I
Israel	Noah	Undergraduate Student	Thurnhoffer	Ben	Graduate Student
Kelson	Suzanne	Graduate Student	Vrettas	Michail	Postdoctoral
Kobayashi	Katie	Undergraduate Student	Wang	Terrance	Undergraduate Student
Liu	Yizhuang	Undergraduate Student	Weiner	Jon	Technician

Lovill	Sky	Graduate Student	West	Patrick	Graduate Student
Mali	Sohil	Undergraduate Student	Wong	Chris	Technician
Marshall	Jill	Postdoctoral	Wood	Todd	Technician

2. Partner Organizations
See attached list

3. Other Collaborators
See attached list

D. Impacts

1. What is the impact on the development of the principal discipline(s) of the project?

The critical zone is a "thing" and, as such, a kind of critical zone science discipline can and should emerge. By practice the network of US critical zones is showing the necessity and fruitful consequence of scientists working across traditionally distinct disciplines: geology, atmospheric science, ecology, tree physiology, microbiology and so on. At Berkeley this is expressed not only in the diversity of fields the 9 PIs represent, but in the fact that students freely work across disciplines, departments and colleges to gain deep insight into integrated critical zone processes. Strong expertise in existing disciplines is still essential, but now such expertise can spread and gain new perspectives in a critical zone context. A new discipline appears to be emerging.

2. What is the impact on other disciplines?
Berkeley PIs are giving talks at the annual meetings in their disciplines and in invited lectures at universities where they are illustrating how the critical zone matters now to their disciplines. This will help attract others into the intriguing science of the critical zone.

3. What is the impact on the development of human resources?

During the past year, 4 post-doctoral researchers, 17 graduate students and 23 undergraduate students conducted research in the ER CZO. Working through the ER CZO has provided these students with invaluable experience in the practical aspects of designing and conducting research projects as well as access to the broad experiences and perspectives of our PIs and senior personnel.

Several graduate students have attained professional positions related to their work at the ER CZO, including 1.) Jasper Oshun is an assistant professor in Geomorphology at Humboldt State University (Arcata, CA), 2.) Percy Link is working in a consulting firm on wind energy development and climate. 3.) Daniella Rempe will start her assistant professor position at the University of Texas, Austin in Fall 2016, 4.) David Dralle is now a postdoctoral researcher with the ER CZO and will be working on a elements of the AWESOM model, 5) Ben Thurnhoffer completed a masters thesis and now works for an environmental consulting company, 6.) Hyojin Kim is currently a post-doctoral scholar at Penn State University and is now working at the Shale Hills Critical Zone Observatory and the Luquillo Critical Zone Observatory.

4. What is the impact on physical resources that form infrastructure?

In June 2015 a new wireless relay station was set up on Cahto Peak, which connects to the Sagehorn Ranch weather station, 22 km away, bringing it online. In October 2015 we replaced wireless equipment on two existing relay stations due to storm damage. Also in October the Vadose Zone Monitoring System was brought online. November 2015 had a second round of emergency storm repairs.

As described in Section A 2, we successfully installed the Vadose Zone Monitoring System at the Rivendell site. This is the first time such a system has been used in a critical zone observatory. This system enables us to monitor at about ~1.5 m intervals through the vadose zone and into the groundwater (to a depth of about 16 m) the moisture content, pressure, and temperature and sample water and gas. This will be the key system for future studies of solute chemistry evolution.

5. What is the impact on institutional resources that form infrastructure?

The primary field site for the ER CZO is the Heath and Marjorie Angelo Coast Range Reserve (Angelo). Angelo is one of 39 protected natural areas managed by the University of California Natural Reserve System (UCNRS). These areas are maintained by University for the purposes of research, education and public service. Various monitoring apparatuses exist and many of these sites and the UCNRS as recently committed to making near real-time biological, hydrological and meteorological data available to the broader research community.

The UCNRS is providing salary support to ER CZO personnel Chris Wong (field technician), Wendy Baxter (field technician) and Virginia Ogle (database administrator) to establish and maintain a network of weather stations and to create a database structure to enable access to various data streams generated at the UC reserves. This effort is being modeled after the ER CZO's sensor database, which Virginia Ogle created and will continue to be supported by UCNRS beyond the lifetime of the ER CZO award.

6. What is the impact on information resources that form infrastructure?

During the 2015-2016 funding period the ER CZO sensor database has been stable. Work has focused on accommodating the partnership with the UCNRS reserves, bringing roughly 300 million more records into the database. The Vadose Monitoring System (VMS) and Sagehorn Ranch weather stations and 3 wells have been incorporated into the realtime system as well.

7. What is the impact on technology transfer?

Nothing to report.

8. What is the impact on society beyond science and technology?

ER CZO researchers, anchored by Co-I Mary Power, have participated in many outreach efforts. In addition to various speaking engagements and meetings (some listed below) we have been involved in several long-term collaborative partnerships, some of which are ongoing. ER CZO has strong interactions with the very active citizen's river watch group, the Eel River Recovery Project (ERRP). We coordinate and share data from joint temperature, fish, native frog, invasive snail and crayfish, and algal, cyanobacterial, and cyanotoxin monitoring efforts distributed throughout much of the 9546 km^2 Eel River basin. These riverine biota are supported, or stressed, depending on the nature, timing, and magnitude of delivery of several Critical Zone currencies (water, heat, solutes, and sediments) to channel networks. CZO researchers regularly attend and speak at ERRP watershed meetings, and ERRP members and leaders speak and participate in our short Angelo Reserve courses and workshops.

Neutrotoxi cyanobacterium

PhD candidate Keith Bouma-Gregson and Mary Power are in increasing communication and exchange with agencies (United States Geological Survey, State Water Quality Control Boards, EPA) and other researchers (UC Santa Cruz, Dr. Raphael Kudela; Cal State Univ., San Marcos, Dr. Rosalina Hristova) tracking freshwater and coastal marine harmful algal blooms. A neurotoxic cyanobacterium of emerging concern in the Eel Basin, *Phormidium*, has been linked to widespread serious public health problems in New Zealand. Bouma-Gregson reached out to New Zealand graduate student Tara McAllister, who is working on *Phormidium* blooms with Professor Susie Wood at Univ. Canterbury, a leading scientist studying cyanobacteria in New Zealand rivers. Tara visited our field site this spring, and plans to return for a longer field study in summer 2018. *Phormidium* harmful algal blooms are advanced in New Zealand, and may presage the situation in semi-arid rivers of the western US (e.g. the Eel and the Russian Rivers of western CA), which show initial changes in this direction.

Algal Foray 2015

On June 12-14, 2015, the ER CZO hosted the 3rd biennial Eel River Algal Foray at the Angelo Reserve. Algal experts Dr. Paula Furey and Professors Rex Lowe and Yvonne Vadeboncoeur came out from Minnesota, Wisconsin, and Ohio, respectively, to teach our neighbors and students from the Eel, Klamath, and other North Coast watersheds how to identify the major taxa of algae in the Eel River and other rivers of the California North Coast. This two-day event was attended by 30 Eel, Russian and Klamath River stake holders, students and teachers. They learned about beneficial and potentially toxic algae by collecting it in various field sites and then identifying it (with Paula and Rex's guidance) under microscopes set up at the Angelo Reserve.

Collecting, microscopy, networking over meals and campfires, were punctuated with presentations and discussions from visiting scientists and ERCZO students, and by attending algal foray participants who have been monitoring the Eel and the Klamath ecosystems for years: Eli Asarian (River Bend Sciences), Mike Deas (WaterCourse Engineering, Inc), and Pat Higgins (Eel River Recovery Project). Many encouraging observations by Pat Higgins and the Eel River Recovery Project of habitat changes and salmon, steelhead, and even sturgeon in the Eel reflect recovery from the logging era. Unfortunately, this recovery is threatened by erosion, pollution, and increased summer water extraction for expanding marijuana cultivation. We need to understand how land and water use, climate, and ecological interactions, all mediated by critical zone processes, can tip the Eel between cyanobacterially degraded and salmon-supporting states. Looking at the base of the food chain, at the algae that are eaten but not seen, versus those that are seen but not eaten, can guide us towards better understanding of how to keep rivers of Northern California on a trajectory towards ecological recovery.

Steelhead and invasive fish

ER CZO PhD students Gabe Rossi and Suzanne Kelson are working directly on steelhead populations. ER CZO PhD student Phil Georgakakos is doing his dissertation work on an invasive piscivorous fish, pike minnow, that threaten native salmonids and other fishes, particularly in warming rivers. ER CZO Undergraduate Noah Israel is studying the impacts of warming on a native minnow. All of these fish studies are of direct interest for (and have received financial and other types of support from) California Department of Fish and Wildlife, CalTrout, Friends of the Eel River, and ERRP.

Workshop June 27 -28, 2016: Hydrologic impacts of changing climate and vegetation cover on summer baseflows in the Eel River, 1950-2016.

Mary Power gave plenary talks on “The Thirsty Eel” at the Salmon Restoration Federation meetings in Fortuna CA (April 8 2016) and the Society for Freshwater Science in Sacramento (May 22 2016). The Fortuna meetings initiated contacts with the Mattole River Restoration Council, leading to a workshop scheduled for June 27-28 on the impacts of forest structure (species dominance, size structure, density) on hydrologic regimes, particularly duration of runoff to channels during drought periods. There will be about 20 participants including researchers from NOAA Fisheries Southwest Fisheries Science Center.

California Water Action Plan: South Fork Eel River

The California Water Action Plan released by CA Governor Brown in 2014 was developed by the California departments of Food and Agriculture, Environmental Protection Agency and Natural Resource Agency *(http://resources.ca.gov/california_water_action_plan/)*. The plan is intended to guide State efforts to enhance water supply reliability, restore damaged and destroyed ecosystems, and improve resilience of California’s infrastructure. A specific sub-action calls to “enhance water flows in stream systems statewide”. The South Fork Eel River was recently selected as one of five stream systems in the state to implement efforts to enhance flows.

On March 23-24, 2016, the Eel River CZO hosted a workshop to discuss collaborations between the CZO, the State Water Resources Control Board and the California Dept. of Fish and Wildlife, and the NGO CalTrout's South Fork Eel Water Program. Representatives from each group participated in discussions and a site visit to the CZO monitoring program. At the workshop, we discussed trends observed in the Eel and its salmonid fisheries, hypotheses regarding flows, forests, and food webs, and the public policy monitoring initiatives being set in motion by the State agencies in response to the California drought. One outcome of the meeting is that CalTrout will provide summer support for ER CZO graduate student Gabe Rossi to do field to work to document limiting factors for juvenile salmonds rearing in the Eel River.

Additional talks:
January 24, 2016. Mary Power gave an invited lecture at a Gordon Conference in Ventura CA on "Depth, Size, Fear and Bathymetry in river fishes".

Februrary 12, 2016. Mary Power gave the Wildlife Conservation talk in ESPM at UC Berkeley on "The Thirsty Eel: Alternate states in algal based river food webs."

March 3, 2016. Mary Power gave guest lecture in Water Planet course at UC Berkeley on "The Secret Life of Rivers"

March 23-24, 2016. Mary Power and William Dietrich hosted workshop for CalTrout, DFW, and Regional Water Quality Control Board agents at the Angelo Reserve to discuss the New CA State Water Plan, which prioritizes S. Fork Eel as one of 5 rivers statewide for special management reconsideration.

April 4, 2016. Mary Power gave the departmental seminar in Environmental Sciences at UC Santa Cruz on "The Thirsty Eel."

April 8, 2016. Mary Power gave a plenary talk at the Salmon Restoration Federation annual conference in Fortuna CA on "The Thirsty Eel."

April 15, 2016. Mary Power gave talk to represent ERCZO and Angelo Reserve at the BigCB UCNRS faculty retreat at Pt. Reyes (the newest UCNRS reserve).

April 16, 2016. Mary Power and Angelo Reserve Steward, Peter Steel, educated several hundred public visitors on ER CZO research on CalDay, when Berkeley welcomes parents, alums, and the general public to discuss research and teaching.

May 22, 2016. Mary Power gave First Plenary talk on Drought, floods, and alternate states of algal-based river food webs in the Thirsty Eel at the Society for Freshwater Science meetings in Sacramento CA.

June 27-28, 2016. William Dietrich and Mary Power hosted Douglas fir workshop at Angelo to include representatives from NOAA fisheries Santa Cruz (Tommy Williams, Nate Mantua) Mattole River watershed restoration council, and other interested professionals working in the North Coast (Eli Asarian, Riverbend Science) to discuss: Is lack of forest clearing by cool fires allowing dense Douglas fir to deplete runoff to the rivers of the CA North Coast?

Sept. 24, 2016. Mary Power will give a departmental seminar at the University of Arkansas, Fayetteville AR.

E. Changes/Problems

1. Changes in approach and reasons for change

N/A

2. Actual or anticipated problems or delays and actions or plans to resolve them

N/A

3. Changes that have significant impact on expenditures

We have reduced our budget request by $8,000. It is our understanding that this money will be used to support the cross-CZO post-doctoral researcher.

4. Changes in use or care of human subjects

N/A

5. Changes in use or care of vertebrate animals

N/A

6. Changes in use or care of biohazards

N/A

F. Special Reporting Requirements

Metrics

Five milestones and their metric of progress (in color)	Status
Milestone 1. Does lithology control rock moisture availability to plants and therefore overall resilience of vegetation to climate change in seasonally dry environments?	
1.1 Compare relative water potential gradients and plant water use on north vs. south facing slopes on mudstones at the Rivendell site.	Monitoring continues
1.2 Compare observations on mudstones with similar data collected on mélange (the Shire- now referred as Sagehorn).	Sagehorn monitoring established
1.3 Model moisture storage and transport, evapotranspiration, and other energy balance components for hillslopes under different aspects, lithology, and vegetation.	Base model constructed
Milestone 2: How are solute and gas effluents from hillslopes influenced by biota in changing moisture regimes?	
2.1 Examine the mobilization, transport and delivery of chemical species from subsurface waters to Elder Creek and then further downstream.	ongoing
2.2 Determine temporal dynamics and biotic origin of high CO_2 and other atmospherically reactive gases within the critical zone.	Continue monitoring of CO2 and O2, now including depth profiles using the VMS system
2.3 Characterize the microbial community over time and with depth into the Critical Zone.	Ongoing initial analyses completed
Milestone 3: What controls the spatial extent of wetted channels in the channel networks of seasonally dry environments?	
3.1 Map the extent of wetted channels during summer low flow for varying lithology, topography and precipitation.	Completed surveys, data analysis underway
3.2 Establish a network of runoff and stream temperature monitoring and use that to motivate and test models of water transport and in-stream energy balance.	Network expanded to two mélange watersheds
3.3 Characterize drawdown, flow and temperature oscillations in Russian River using the existing flow gauge network.	Developing analytical framework
3.4 Develop and test models of stream network contraction during summer low flow.	Model under construction
Milestone 4: Will changes in critical zone currencies induced by climate or land use change lead to threshold-type switches in river and coastal ecosystems?	
4.1 Compare algae and cyanobacteria production at three main-stem South Fork Eel reaches that experience different radiation and flow regimes.	Survey expanded to sites downstream and to mainstem
4.2 Monitor salmonid performance in two tributaries of the South Fork Eel.	Monitoring expanded to include genetic surveys
4.3 Develop coupled biological-physical models for the study reaches.	Model under development
Milestone 5: Synthesis Modeling (the Atmospheric, Watershed, Ecology, Stream, and Ocean Model)	
5.1 Assemble pre-existing model components.	Model ready to connect to CLM
5.2 Develop and test models for hillslope scale groundwater recharge and discharge incorporating the effects of preferential fracture flow.	Model developed with intention to like to CLM

	5.3 Develop and test model for species- and lithology-specific water uptake from the critical zone.	Samples collected from both Rivendell and Sagehorn and being analyzed
	5.4 Develop and test models of the diurnal oscillations in flow and stream temperature for entire stream network.	Continued analysis, model development underway
	5.5 Project from AWESOM the effects of climate and land use change on future critical zone currencies.	Developed plans to link hillslope model to channel network runoff model

CZO Network Activities

1. Participation in CZO network meetings.

a) ERCZO PIs participated in meeting that led to a document reporting the CZO strategic plan

b) CZO Data Managers working group: as an organic response to concerns from both PI's and Data Managers across the CZO network, the Data Managers have formed a working group to discuss management needs and potential centralization of data management systems. ER CZO Data Manager Collin Bode is actively participating in the group, attending meetings on Dec. 9 2015, March 3 2016, and May 10 2016. Collin has also reached out to the CZData research group (Jeff Horsburgh, Leslie Hsu) to get their input.

c) PhD Candidate Evan Starr attended the CZO Microbial Ecology Workshop at Argonne National Lab, where he helped formulate a plan for a cross CZO microbial ecology sampling and analysis effort.

2. Cross-site collaborations:

a) Shale Hills- (Brantley) neutron scattering to measure porosity changes due to weathering of shale bearing turbidites.

b) Post-doc Jill Marshall is working across Boulder, Southern Sierra and Eel River CZOs. She is working to parameterize and calibrate a soil production function for forested landscapes based on observations of the mechanics of root-driven bedrock damage and detachment, using observations at each of the CZOs.

c) Hyojin Kim completed her PhD with research at the ER CZO and is now doing comparison work at the Shales Hill and Luquillo CZOs.

d) ERCZO will collaborate on a CZO wide post-doctoral research project on the controls of critical zone architecture on hydrologic processes.

e) A Strategy for Advancing Critical Zone Science
PI's Dietrich and Thompson participated in the February 2016 retreat which produced the "A Strategy for Advancing Critical Zone Science " statement that defines the CZO Mission and Core Values and Major Goals.

4. International CZO

CZEN post-doc Dr. Allison Oliver (University of Alberta, Canada) has recently begun work at the ER CZO. She will be studying carbon and nutrient exports from the Eel River. We have also continued our engagement of Dr. Dedi Liu of Wuhan University (China) who is working with ER CZO researchers to develop a hydrological model for the entire Eel River system to explore climate change and water use effects on stream flow and temperature.

CZO Program Budgets

SUMMARY PROPOSAL BUDGET				**FOR NSF USE ONLY**	
ORGANIZATION **University of California, Berkeley**				PROPOSAL NO.	DURATION (MONTHS) Proposed / Granted
PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR **William E. Dietrich**				AWARD NO.	
A. SENIOR PERSONNEL: PI/PD, Co-PIs, Faculty and Other Senior Associates List each separately with name and title. (A.7. Show number in brackets)	NSF-Funded Person-months CAL	AC	SUMR	Funds Requested By Proposer	Funds Granted by NSF (If Different)
1. **William E. Dietrich – PI**	0.0	0.0	0.50	$**10,063**	$
2. **James K. Bishop**	0.0	0.0	0.25	**3,870**	
3. **Stephanie M. Carlson**	0.0	0.0	0.25	**2,175**	
4. **Mary E. Power**	0.0	0.0	0.25	**2,870**	
5. **Sally Thompson**	0.0	0.0	0.25	**2,812**	
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)	0.0	0.0	0.0	**0**	
7. (**5**) TOTAL SENIOR PERSONNEL (1-6)	0.0	0.0	1.50	**21,799**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**2**) POSTDOCTORAL ASSOCIATES	14.5	0.0	0.0	**84,894**	
2. (**2**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	24.0	0.0	0.0	**64,409**	
3. (**5**) GRADUATE STUDENTS				**161,877**	
4. (**5**) UNDERGRADUATE STUDENTS				**19,200**	
5. ( ) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. ( ) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**360,179**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**163,178**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**515,357**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				**34,518**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT 1. STIPENDS $ 0 2. TRAVEL 0 3. SUBSISTENCE 0 4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**31,902**	

2. PUBLICATION/DOCUMENTATION/DISSEMINATION	**0**	
3. CONSULTANT SERVICES	**0**	
4. COMPUTER SERVICES	**0**	
5. SUBAWARDS	**80,214**	
6. OTHER	**36,845**	
TOTAL OTHER DIRECT COSTS	**148,961**	
H. TOTAL DIRECT COSTS (A THROUGH G)	**698,836**	
I. INDIRECT COSTS (F&A) (SPECIFY RATE AND BASE) **MTDC (Rate 57.000, Base: 492706)**		
TOTAL INDIRECT COSTS (F&A)	**293,164**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)	**992,000**	
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECT SEE GPG II.D.7.j.)	**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)	$**992,000**	$

M. COST SHARING: PROPOSED LEVEL $ **0**	AGREED LEVEL IF DIFFERENT: $			
PI/PD TYPED NAME AND SIGNATURE* **William E. Dietrich**	DATE	**FOR NSF USE ONLY** INDIRECT COST RATE VERIFICATION		
ORG. REP. TYPED NAME & SIGNATURE*	DATE	Date Checked	Date of Rate Sheet	Initials-ORG

NSF Form 1030 (10/99) ***Supersedes All Previous Editions*** *SIGNATURES REQUIRED ONLY FOR REVISED BUDGET (GPG III.C)

We anticipate spending according to our proposed Year 3 budget.

Budget Justification – CZO Award

Senior Personnel

Two weeks of summer salary are planned for the PI for project management purposes. The PI serves as Director of the Eel River CZO, participates in CZO teleconferences, contributes to National CZO activities (such as writing basic documents), holds monthly meetings of the Eel River CZO community, contributes to outreach, gives lectures about the CZO, supervises budgetary matters, supervises staff, participates in National CZO meetings, mentors CZO students, and reports on Eel River CZO activities to NSF. One week of summer salary is included for the co-PIs who form the Executive Committee. This committee aids the PI in making administrative decisions, governing the research programs, and overseeing the progress of the CZO as a whole. The other senior personnel are faculty collaborators (Fung, Dawson, Firestone and Banfield) do not take on administrative duties. All the senior personnel contribute to management decisions concerning general operations and guiding the CZO toward its prescribed goals.

Other Personnel

Our data manager, informatics specialist, and general field instrumentation support staff person, Collin Bode is supported 43% time through the CZO. He is responsible for the informatics infrastructure including, but not limited to the wireless network, operating and maintaining the sensor observatories, developing and maintaining the sensor observatory database and website for archiving and disseminating data, and performing spatial.

We will support a 13% time position for programming support to maintain the data flow and its accessibility. Virginia Ogle, the programmer who designed the original databases, will be employed to help avoid inherent data issues and structure problems, as well as improve data availability and accessibility. We have reduced the effort of Virginia Ogle from 20% to 13% to account for $8,000 to be used to support the cross-CZO post-doctoral researcher.

Postdoctoral Scholars:

The modeling work will be accomplished by two postdoctoral scholar who will interact with each other and modelers at other CZOs. This work builds upon our field observations and requires advance knowledge and skills, hence the choice of postdoctoral scholar support.

Graduate student research assistants:

A group of five graduate student researchers (GSRs) will take the primary responsibility for the fieldwork, laboratory analyses, and some modeling associated with each of our four questions. Through rotation as graduate student instructors, fellowships, and other sources of funding we anticipate the graduate group working at the CZO will be much larger than that supported by this grant. Salary is for GSRs at 50% effort during the academic year and 100% effort during the summer period.

Undergraduate Assistants:

The intensive fieldwork associated with our proposed research will benefit from and will provide an excellent learning opportunity for undergraduate research assistants. We anticipate at least four to six undergraduates working part-time with CZO researchers, especially in the summer 2017 field season.

Fringe Benefits

Benefits for the PI and co-PIs is projected to be 18.10% of payroll. For the Specialist benefits have been calculated at 36.80%. For the programmer benefits are calculated at 44.60%. Postdoc benefits are calculated at 18.10% and graduate student and undergraduate research assistant benefits at 0.0%. In addition, funds are budgeted for the graduate students' fee remission (in-state fees), which is included in the fringe benefit line item. Graduate students who are supported at 45% or more time are eligible for the full fee remission (including non-resident tuition), which includes coverage of the SHIP fee plus campus fees. It is UC Berkeley's practice to similarly compensate students in non-sponsored as well as sponsored activities.

Travel

Travel funds for fieldwork will cost $34,518. This covers cost of car rental for graduate students, fuel, food, and lodging. All four of our research questions require extensive fieldwork. Three of the four questions entail focused research in the Angelo Coast Range Reserve, which is 360 miles of travel roundtrip from Berkeley. Fieldwork based at the Angelo Reserve requires a daily fee (includes being able to camp or stay in one of the buildings) of $12 per person. Fieldwork involves groups of graduate students, undergraduates and senior personnel. These researches will make frequent short trips all year long, but also spend significant periods of the summer in the field. Question (1) and Question (3) require extensive travel outside of the Reserve to monitor a site in mélange and to conduct two stream flow network surveys. Additional travel costs are included to support travel (including registration fees for CZO students) to the semi-annual face-to-face meetings with other CZO PIs held each fall at the American Geophysical Union meeting, and in conjunction with spring annual PI meetings.

Materials and Supplies

The materials and supplies budget accounts for (1) further installation costs for monitoring system on the mélange bedrock (e.g. pressure transducers, weather monitors, moisture detection, data storage and batteries), (2) the annual maintenance of the Rivendell and Sagehorn Ranch systems (e.g. cables, monitoring equipment, radio replacement) (3) annual replacement costs of portable monitoring devices for the wetted channel surveys (based on experience this difficult work leads to the need to replace most of the instruments several times a season, which includes GPS, portable air and water thermometer, relative humidity, and digital camera) and (4) expendable supplies (e.g. pit tagging materials, nets, iButtons, balances, oxygen meters, and current meters) for stream field work. Total for these four expenses is $31,902.

Budget – LBNL Subaward

SUMMARY PROPOSAL BUDGET

					FOR NSF USE ONLY		
ORGANIZATION **Lawrence Berkeley National Lab**					PROPOSAL NO.	DURATION (MONTHS)	
						Proposed	Granted
PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR **Todd Wood**					AWARD NO.		
A. SENIOR PERSONNEL: PI/PD, Co-PIs, Faculty and Other Senior Associates List each separately with name and title. (A.7. Show number in brackets)	NSF-Funded Person-months			Funds Requested By Proposer	Funds Granted by NSF (If		
	CAL	AC	SUMR				
1. **Todd Wood**	0.0	0.0	0.0	$**23,678**	$		
2.	0.0	0.0	0.0				
3.	0.0	0.0	0.0				
4.	0.0	0.0	0.0				
5.	0.0	0.0	0.0				
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)	0.0	0.0	0.0	**0**			
7. (**5**) TOTAL SENIOR PERSONNEL (1-6)	0.0	0.0	1.50	**23,678**			
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)							
1. (**0**) POSTDOCTORAL ASSOCIATES	14.5	0.0	0.0	**0**			
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	24.0	0.0	0.0	**0**			
3. (**0**) GRADUATE STUDENTS				**0**			
4. (**0**) UNDERGRADUATE STUDENTS				**0**			
5. ( ) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**			
6. ( ) OTHER				**0**			
TOTAL SALARIES AND WAGES (A + B)				**23,678**			
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**0**			
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**23,678**			
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)							
TOTAL EQUIPMENT				**0**			
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				**1,800**			
2. FOREIGN				**0**			
F. PARTICIPANT SUPPORT 1. STIPENDS $ 0 2. TRAVEL 0 3. SUBSISTENCE 0 4. OTHER 0							
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				**0**			
G. OTHER DIRECT COSTS							
1. MATERIALS AND SUPPLIES				**0**			
2. PUBLICATION/DOCUMENTATION/DISSEMINATION				**0**			
3. CONSULTANT SERVICES				**0**			
4. COMPUTER SERVICES				**0**			
5. SUBAWARDS				**0**			
6. OTHER				**26,751**			
TOTAL OTHER DIRECT COSTS				**26,751**			
H. TOTAL DIRECT COSTS (A THROUGH G)				**52,229**			
I. INDIRECT COSTS (F&A) (SPECIFY RATE AND BASE) **MTDC (Rate 54.6150%, Base: 48094)**							
TOTAL INDIRECT COSTS (F&A)				**27,985**			
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**80,214**			
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECT SEE GPG II.D.7.j.)				**0**			
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$**80,214**	$		
M. COST SHARING: PROPOSED LEVEL $ 0	AGREED LEVEL IF DIFFERENT: $						

<table>
<tr><td>PI/PD TYPED NAME AND SIGNATURE*
Todd Wood</td><td>DATE</td><td colspan="3">FOR NSF USE ONLY
INDIRECT COST RATE VERIFICATION</td></tr>
<tr><td>ORG. REP. TYPED NAME & SIGNATURE*</td><td>DATE</td><td>Date Checked</td><td>Date of Rate Sheet</td><td>Initials-ORG</td></tr>
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NSF Form 1030 (10/99) ***Supersedes All Previous Editions*** *SIGNATURES REQUIRED ONLY FOR REVISED BUDGET (GPG III.C)

Budget Justification – LBNL Subaward

The Year 3 subaward to the Lawrence Berkeley National Lab will be $80,214, which includes:

Senior Personnel

Todd Wood (Sr Scientific Eng Associate) (1.5 months) is responsible for modifying/designing and implementing electronics and firmware for automated water sampling at new Eel River sites. He deploys power/network infrastructure at 2 Eel River sites for real-time data acquisition and instrumentation control. He maintains instrumentation and datasets and supervises students performing water chemistry and trace metal analysis.

Travel

Estimated travel costs (car rental/gas) for a trip is approximately $300 per trip. It is anticipated that six trips will be required to maintain sampling activities. Total cost $1,800.

Additional Costs

Additional costs (Other) include: 1) support of existing ISCO controllers at Angelo Reserve well/creek sites; 2) analysis of trace metal and water chemistry of collected samples; 3) anticipated repair /replacement of system components such as pumps, electronics and tubing; and 4) data transmission charges for cellular or satellite modems. Total cost for these expenses are $26,751.

Additional Funding

In our third year, ER CZO has received the following new awards:

PI: Inez FungTitle: High-Frequency and Vertical Variations of Soil Moisture and their Impact on Ecosystem Dynamics
Sponsor: Department of Energy
Total Award: $481,352
Start-End Dates: 8/1/15 - 7/31/18.
CalTrout: $10,000 to Gabe Rossi (Graduate Student)

UCNRS Mildred Mathias Grants

$2000 to Gabe Rossi (Graduate Student)

$2000 to W. Jesse Hahm (Graduate Student)

UC Berkeley Integrative Biology Summer Research Award: $1750 to Philip Georgakakos (Graduate Student)

Phycological Society of America: $925 to Keith Bouma-Gregson (Graduate Student)