Effectiveness Monitoring Committee

Full Project Proposal Form

Deadline for Submission: November 16th, 2019

Project #:

Date: 11/15/2019

Project Title: Fuel Treatments and Hydrologic Implications in the Sierra Nevada

Principal Investigator(s):
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Collaborators:
The Nature Conservancy
USFS (Tahoe National Forest)

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Project Duration (Years/Months): 2 / 0

Written Proposal Requirements:

Please address each of the following for consideration by the EMC. For further information please see the Request for Proposals or consult section 5.0 of the EMC's Strategic Plan.

1. **Background and Justification**
2. **Objectives and Scope**
3. **Critical Questions and Forest Practice Regulations Addressed**
   Please identify the Critical Questions by number and letter (as identified in the EMC's strategic plan), and the associated regulations by number. Please also describe how your project will address these questions and the efficacy of each regulation.
4. **Research Methods**
5. **Scientific Uncertainty and Geographic Application**
   Please consult section 4.4 of the EMC's strategic plan for further information.
6. **Collaborations and Project Feasibility**
7. **Project Deliverables**
8. **Detailed Project Timeline**
9. **Requested Funding**
   Please provide the total requested amount of funding along with a line item budget for each fiscal year of the project (see page 2).

Include figures, tables, or photos as needed.

Please ensure that all "Categories" below are addressed in your budget. This will ensure that all information required by the state contracting process is present. You may break each "Category" into as many sub-categories as needed to fully describe your budget.

Category	Description	Year 1	Year 2	Year 3	Total
Personnel *Identify all personnel costs including field technicians, graduate students, Principal Investigators, etc.* ***Show these values as individual rates per unit of time.***	**PI**	991	1,021		2012
	Graduate Student	12,000	12,360		24,360
Fringe Benefits *Cite as actual benefits or a percentage of personnel costs.*					
	Fringe Benefit	418	438		856
	Tuition, Fees, Health Ins (grad student)	11,948	12,425		24,374
Other	Subaward	**37,350**	**37,438**		**74,788**
Operating Expenses *Include rent, supplies, and equipment costs as separate line items*	supplies	500	500		1000
Indirect Cost *Not to exceed 15%*	**IDC**	16,471	6,806		23,277
Travel *Express as per diem rates specified by CalHR, or verification that such rates are not available to you.*	Field Site Visit (Sagehen)	**3000**	**3000**		**6000**
Total Cost					
Matching or In-Kind Contributions					
EMC Funding Requested		82,677	73,989		156,665

Fuel Treatments and Hydrologic Implications in the Sierra Nevada

1. Background and Justification

The forested Sierra Nevada range acts as a natural reservoir collecting vast quantities of snow, which provides the majority of hydrologic needs for municipal, industrial, and agricultural sectors of California, and Reno Nevada (Margulis et al., 2016, Sterle & Singletary, 2017). These forested landscapes are changing in response to intensifying climate, fire patterns, and biological invasion (Slingsby et al., 2017). Decadal decreases in snowpack have altered the Sierras' capacity to provide water to a multitude of competing demands (Belmecheri et al., 2016). Thus, land managers are experimenting with more preventative forest management strategies to reduce forest fire risk and increase water quantity (North et al., 2015).

Changes in forest structure (thinning, mastication, logging, wildfire, etc.) have implications for local and regional water quantity and quality. Changes in basin yield are noted to be a function of regrowth rate, canopy cover and soil properties (Saksa et al., 2017). Given the dependency of the western U.S. on snowpack and mountain runoff for water supply (Painter et al., n.d.; Pierce et al., 2008); a minimal change of the current forest structure can have critical implications for regional and state water resources. Thus, ecohydrologic projects that monitor fuel management and forest stand treatments are needed, especially longer-term high-resolution studies (monthly and seasonal vs. traditional annual scale).

Studies evaluating the hydrologic response to forest fires have noted that there can be increases in water yield following reductions in forest structure (Kinoshita & Hogue, 2015; Hallema, 2018; Evaristo & McDonnell, 2019). Similarly, studies have noted that forest treatments can impact water yield (Hibbert, 1965; Rothacher, 1970; Rector and MacDonald, 1987; Saksa et al., 2017). This work will build and complement previous studies conducted in the Sierra Nevada's (Bales et al., 2011; 2015). For example, the SNAMP project tested the impacts of implementing strategically placed area treatments (SPLATs) at two different Sierra Nevada sites for water quality and quantity. The Regional Hydro-Ecologic Simulation System (RHESSys) model was calibrated and utilized, but further work is needed to incorporate fireshed scale. The study findings of changes in forest structure were determined by differences in LAI and overstory canopy cover can be investigated for current use within this proposed work.

We will utilize and assess our uniquely instrumented sub-nested watersheds and to not only evaluate the cumulative impacts of treatments at the watershed scale, but also the specific impacts of varying treatments at the subwatershed scale. We anticipate that there will be changes in water yield however, given current climate projections, modern forest conditions, and management techniques, we are unsure how treatments will impact water yield. Previous works have noted that expected increases in water yields are not always observed in practice (Ziemer, 1986). This is congruent with current studies that show that treatments in Mediterranean climates can have negligent or even negative impacts on water yield when climatic influences are accounted for (Tague et al., 2019, Kurzweil et al., 2019). While these studies provide insight into the complex interactions between changes in land cover and water quantity and quality, new forest treatments such as SPLAT, which could greatly improve forest resiliency, diversity and water yield (USDA, 2011) have not been studied with relation to water yield.

The Sagehen Experimental Forest is representative of the modern forest conditions found throughout the Sierra Nevada and Western U.S. (USDA, 2011). Sagehen is undergoing extensive and variable experimental treatments guided through SPLATs. The goal is to fragment the landscape, reducing fuels (forest stands) and ultimately, extent and severity of regional fires (Bahro et al., 2007). The Forest Service is managing the Sagehen basin in order to: 1) reduce hazardous fuel loads and modify wildfire behavior, 2) maintain and enhance habitat for wildlife (i.e. American marten, California spotted owl, and northern goshawk), 3) encourage a healthy forest fire regime, 4) create heterogeneous forest conditions natural to an active fire regime, and 5) restore declining aspen stands. The implementation of the SPLATs are expected to serve as a prototype for forest management for the Sierra Nevada, as outlined in the USFS General Technical Report, "An Ecosystem Management Strategy for Sierran Mixed-Conifer Forests" (North et al., 2009).

By monitoring and evaluating these goals, this study will assess the effectiveness of natural resource protection of forest structure and health through wildfire hazard reduction and the cumulative hydrologic and habitat impacts these practices have. Specifically this study can lead to an improved physical process-based understanding of fuel treatment activities conducted under the California Forest Practice Rules (FPRs) (Crowfoot & Porter, 2019). We will be evaluating a multitude of forest stand treatments outlined in the SPLAT methods. This includes uneven-aged management, intermediate treatments, commercial thinning, and Aspen restoration. We will be evaluating the cumulative effects of treatments on changes in hydrologic behavior, which have important implications for determining if the quantity and beneficial uses of water has been unreasonably degraded, with the aim that it will improve. For the preparation of timber harvesting plans, this will provide critical data and understanding for evaluating the effects of fuel treatments as required under 14 CCR 15355. We are uniquely positioned to evaluate the cumulative impacts of forest treatments on the hydrologic response due to treatments happening over time. This will allow us to evaluate not only the impacts of a specific treatment, but also the impacts of compounding treatments. We are also able to evaluate the cumulative impacts of treatments at the catchment and sub catchment scale from our network of eleven in situ stream gages. Each gage represents a variation in treatment, treatment intensity and vegetation structure allowing for detailed analysis under multiple treatment scenarios. Additionally, hydrologic impacts of hazard reduction including broadcast burning of slash under 14 CCR § 937 will be evaluated.

To date, no studies take advantage of this unique opportunity to monitor and evaluate the potential range of hydrologic changes that will occur in the basin given the variety of treatments being applied. We have developed an extensive in situ observational network in Sagehen, supplemented with ground-based surveys and remote sensing information (pre and post-treatment data at sub-basin scales for each treatment type since 2012). With the largest amount of forest treatments occurring in 2018 it is imperative that monitoring Sagehen continues as this unique dataset allows us to evaluate the impact of forest treatments on critical ecohydrologic processes at a range of space and time scales not previously undertaken.

2. Objectives and Scope

The overarching goal of this research is to monitor, analyze, and develop statistical and physically-based models to quantify the response of streamflow to cumulative forest treatments in Sierra Nevada watersheds. Results will significantly advance and transform our understanding of the impacts of fuel treatments on short- and long-term water yield in sub-alpine mountain systems and provide critical information for regional forest and water resource managers and planners. The proposed work also presents an opportunity to build upon and bridge interdisciplinary resource managers (water, forest, power, etc.) to jointly manage multiple and critical resources. In addition to our extensive monitoring, we propose the development of a predictive framework that is transferable to regional watersheds for quantifying stream and hydrologic response to relevant mitigation efforts. The proposed work also builds upon our extensive research on understanding and predicting hydrologic behavior in altered watersheds, which includes collaborations with the U.S. Forest Service, the Bella Vista Foundation, and The Nature Conservancy, as well as our ongoing research activities in the Sagehen basin.

Our research questions include:

- *How will cumulative and variable forest treatments affect sub-basin and basin scale hydrologic response?*
- *What key variables determine hydrologic response to differing mitigation strategies?*
- *To what degree can remote sensing information quantify treatment impacts on forest structure?*
- *To what degree can in situ data help to parameterize a physically-based hydrologic model for fuel treatment assessment?*
- *To what degree will the developed model improve prediction of cumulative effects on hydrologic response from fuel treatments under differing management scenarios?*
- *What key metrics best quantify system change and can be easily integrated into a predictive framework for evaluating habitat and hydrologic response in California watersheds?*

3. Critical Questions and Forest Practice Regulations Addressed

In addition to our main objectives and scope described above, monitoring an extensive forest treatment mitigation program is in line with the California State Board Forestry and Fire Protection formed Effectiveness Monitoring Committee (EMC) to develop and implement a monitoring program to address both watershed and wildlife concerns and to provide a better active feedback loop to policymakers, managers, agencies, and the public. While our proposed work will address several of the EMC themes and critical questions, the nested/hierarchical nature of our study makes it uniquely suited to address cumulative effects in a manner consistent with the strategy proposed in Section 2.2 of the EMC's Strategic Plan.

Of the 11 themes and critical questions identified in the EMC's strategic plan, we will primarily address questions in Theme 6 as described below.

Theme 6: Wildfire hazard

Theme 6 stresses the need to test the assumptions that fuel treatments are meeting the goals and intent of the FPRs as related to water policy and achieving water quality objectives. Since many fuel treatment activities are done under ministerial permits (i.e., Exemptions or Emergencies), it is important to determine whether these activities have impacts on hydrologic processes and/or water quality.

4. Research Methods

4.1 Study Area

The Sagehen basin is ~16 km north of Truckee, California and 32 km north of Lake Tahoe, on the eastern side of the Sierra Nevada. The Sagehen Creek Field Station and Sagehen Experimental Forest were established in 1951 and are operated by UC Berkeley. The 36 km^2 watershed has high biodiversity and is home to large alpine fens, including the largest Mason Fen (USDA & USFS, 2011). There are over 680 plant and 200 vertebrate species documented in the area. There has been active fire suppression, resulting in dense forest growth in over half of the basin. A catastrophic wildfire in this area would have adverse impacts on the diverse biota, natural and cultural resources and the ecohydrology of Sagehen Creek and ultimately the Little Truckee River and Truckee River, which are considered "water quality limited" (Section 303 (d) of the Clean Water Act).

There are four treatments being undertaken within Sagehen: aspen restoration, plantation thin, underburn, and variable thin (Figure 1), each have a specific objective. Initial SPLAT treatments began in 2016. The majority of the treatments were completed during the summer of 2018; with ongoing chipping and mulching still occuring. Given this timeline, we currently have ~4 years of pre-treatment monitoring data and ~3 years of post-treatment monitoring data.

4.2 Sub-watershed and Basin-scale Monitoring after Forest Structure Change

This task involves extensive monitoring, data collection, database compilation and analysis of the collected observations relative to treatment type. An important attribute of Sagehen is the extensive pre-existing climate and hydrological instrumentation, allowing an evaluation of spatial and temporal trends and patterns for historical (~50 years) and contemporary (~10 years) periods. The USGS has monitored stream flow at the outlet since 1953 and Sagehen is instrumented with 11 automated weather stations and flux towers that record a range of parameters at varying elevations throughout the basin. We have also established a pressure transducer sensor network to monitor sub-catchment streamflow since 2012 (Figure 1), which will be used to capture the hydrologic response based on different treatment types. The installed Colorado School of Mines (CSM) network of pressure transducers records stage height and temperature observations every fifteen minutes (installed October 2012) (Figure 1). Sites will be visited 2-4 times per year to gather data and manually measure discharge for rating curves, ultimately providing continuous discharge at each sub-basin and to increase the accuracy of the rating curves.

To maintain accuracy in streamflow measurements, channel cross sections will be re-surveyed as needed when there is significant geomorphic and channel structure change (sediment deposition or scour). Our post-treatment observations will be compared to any relevant surveys such as the USDA Forest Service Stream Survey, 2002 that catalogued geomorphology (https://sagehen.ucnrs.org/research/resources-data/). Available precipitation and other meteorological variables will serve to establish rainfall-runoff relationships within treatments and sub-basin areas. All data gathered from our observational network as well as collected and processed remote sensing data will be available from this study.

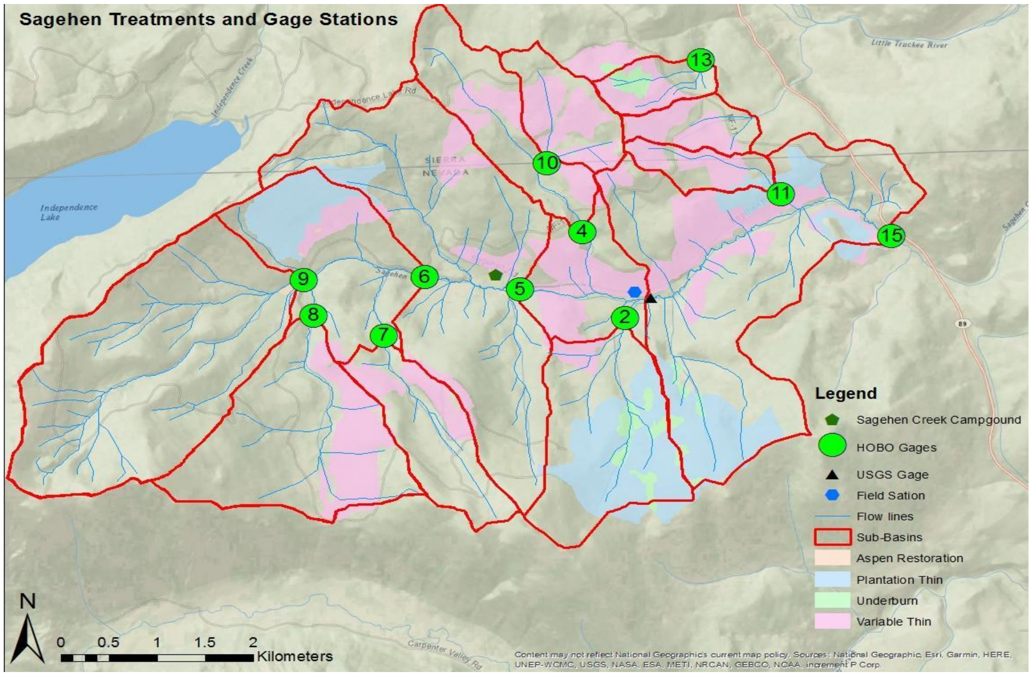

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Figure 1. Sagehen watershed, fuel treatments, and instrumentation

4.3 Remote Sensing of Vegetation

To understand the relations between vegetation cover and streamflow and habitat conditions, a compilation of remote sensing data and analyses will be related to vegetation processes. Remote sensing products can provide spatial and temporal information to monitor seasonal and annual vegetation patterns and detect changes in forest canopy and vegetation structure. These datasets will be used to develop a framework to predict the seasonal and annual hydrologic response to forest treatments and management in the Sierra Nevada.

4.3.1 Normalized Difference Vegetation Index

In our prior work we have applied Normalized Difference Vegetation Index (NDVI), which is a proxy of green biomass or vegetation activity. NDVI uses the normalized difference between red and near-infrared channels and is sensitive to vegetation fraction and the rate of absorption of photosynthetic solar radiation (Gitelson et al., 1996). NDVI is a well-established vegetation index that correlates with photosynthetically active plant material. Indices vary from 0 to 1, where 0 represents no vegetation and 1 is fully vegetated. Landsat derived NDVI has been acquired at 30 m and evaluated from 1996 to present.

Initial work at Sagehen includes seasonal and annual analysis with NDVI and basin outlet discharge, and highlights that there are noticeable trends between vegetation indices and climate patterns (seasonality and dry periods) (Figure 2).

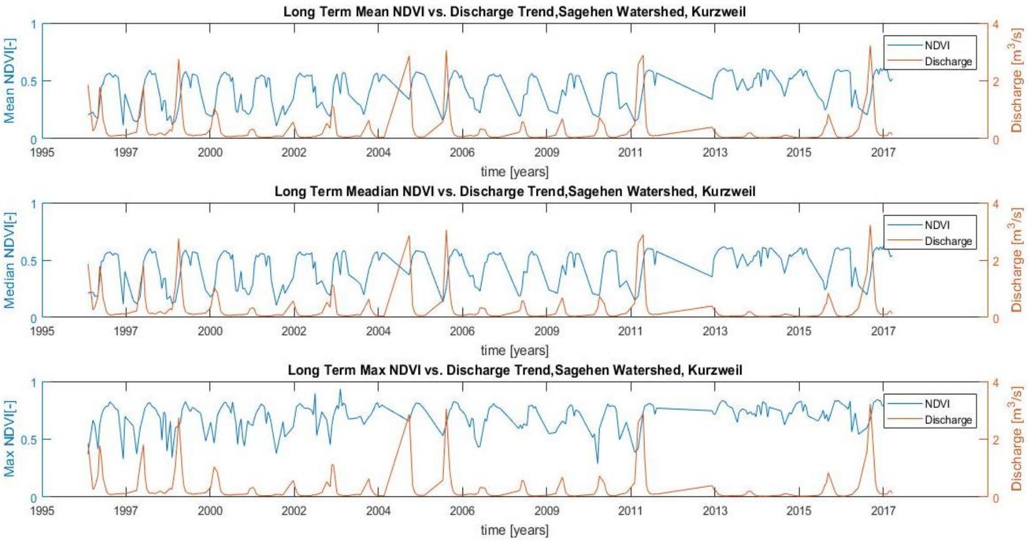

Figure 2: NDVI derived from Landsat (Mean, Median, Max values) and relationship to discharge at the outlet of the Sagehen basin (USGS gage) for water years 1986 to 2017.

We hypothesize that due to drought stress in 2011-2015 there was a decrease in canopy cover, potentially allowing undergrowth and higher growth (green) productivity. Understory species such as *Carax* and *Juncus* are thought to have much higher NDVI values then the coniferous canopy cover (Ramsey et al., 2002). Seasonal variation in the trend of NDVI indicates that additional ground-based and higher resolution information are needed to monitor canopy and vegetation cover and validate and calibrate our remote sensing work. Additional analyses on factors driving these patterns are needed to understand the influence of basin-wide vegetation and discharge variability.

4.3.2 Leaf Area Index

Additional metrics such as Leaf Area Index (LAI) and Light Detection and Ranging (LiDAR) will be incorporated into the vegetation analysis. Leaf area is strongly related to the total amount of plant to atmosphere exchange processes such as photosynthesis, evapotranspiration, rainfall interception, and carbon flux. Canopy leaf area can be estimated by leaf area index (LAI), which is a measure for the total area of leaves per unit ground area and is related to the amount of light that can be intercepted by plants and is an important climate and biodiversity variable (WMO, 2016). An active area of research is working towards evaluating the sensitivity of LAI to forested regions and understory vegetation (Meyer et al., 2019). We will obtain relevant LAI from Landsat scenes (30 m) with no cloud cover from USGS Earth Explorer. LAI will be acquired from 2012 to the end of the proposed project for Sagehen to represent baseline and post-treatment conditions.

4.3.3 Light Detection and Ranging (LiDAR)

Airborne LiDAR data are playing an increasingly important role in forest survey, monitoring, and management (i.e. Jakubowski et al. 2013; Ma et al., 2018) because of their capabilities in characterizing three-dimensional tree structures (Coops et al. 2007). Many studies have demonstrated the efficiency and accuracy of using LiDAR data to estimate forest structure parameters, which we will estimate in the proposed study. These include tree height (Holmgren et al., 2003), canopy cover (CC) (Korhonen et al. 2011), biomass (Tao et al. 2014), percent canopy cover (Griffin et al., 2008), and leaf area index (Jensen et al., 2008; 2011).

We proposed to incorporate available aerial LiDAR data to detect vegetation structure change with respect to the treatments and LAI information described in Section 4.3.2. Sagehen has been part of several aerial LiDAR surveys, which are available from the UC Berkeley Center for Forestry on OpenTopgraphy and the National Center for Airborne Laser Mapping (NCALM). Repetitive point cloud data collection can be used to quantify disturbance-related changes over time and may aid in understanding responses after forest treatments. We will acquire the point cloud data for a pre- and post-treatment LiDAR image. It is anticipated that the point density coverage for these data sets may vary temporally and spatially due to survey conditions such as snow or missing flight swaths. When available, pre-processed data such as derived vegetation height may be used in our analysis, otherwise, a four-part workflow will be used to acquire, process, interpret, and quantify error in the obtained LiDAR datasets similar to Nourbakhsh-beidokhti et al. (2019). Occasional field reconnaissance throughout the proposed study period will be used to help corroborate LiDAR. For example, based on the first quarter of work, we will note areas that require field reconnaissance or points of interest to investigate and spot-check the remotely-sensed vegetation.

Available aerial LiDAR data will be used to derive digital terrain model (DTM), digital surface model (DSM), and canopy height model (CHM) to generate tree height and forest parameters. The DTM and DSM for each dataset will be interpolated from ground and first returns using the ordinary Kriging algorithm (Ma et al., 2019). CHM will be calculated as the difference between the DSM and DTM with a resolution of 0.5 meters, which can be interpolated to relevant cell sizes for comparison with other remote sensing products in this study.

4.3.4 Synthesis of Remote Sensing Data

The forest type in Sagehen and each sub-basin will be classified using the U.S. Forest Service Pacific Southwest Region (R5) Classification and Assessment with Landsat of Visible Ecological Groupings (CALVEG). The vegetation and management type will guide analysis. The remote sensing products, LAI and LiDAR, will be compared for each sub-catchment based on treatment application. Derived information will be incorporated with our understanding of vegetation patterns based on NDVI. Additionally, to validate and supplement the findings above, Landtrendr algorithms will be utilized in the Google Earth Engine interface to evaluate gain or loss of vegetative structure in the watershed (Kennedy et al., 2010; 2018). Landtrendr evaluates the change in the spectral trajectory of individual pixels at 30 m. This method allows for the extraction of the year a change process began, the year a change process ended, the magnitude of change, and the duration of that change, among other calculations.

4.4 Statistical Analysis and Framework Development

In summary, two primary data sets will be collected in Sagehen: 1) surface water data (discharge and water quality) collected via stilling wells, a United States Geological Survey (USGS) station #10343500, in situ weirs, geochemical sampling and macroinvertebrate analysis; and 2) remotely sensed vegetation and canopy information (NDVI, Landtrendr, LAI, LiDAR).

We will assemble sub-catchment data to characterize physical conditions that influence streamflow, habitat conditions, sediment flux and vegetation relations such as hillslope, treatment applications, and other metrics that quantify vegetation biomass loss. Synthesized LAI and LiDAR information with seasonal and timeseries data (i.e. NDVI and streamflow) will be used to construct the framework for predicting restoration impacts on watershed processes.

Discharge data collected in the eleven subwatersheds, from 2012 to present, will be used to evaluate the hydrologic and habitat response to forest management practices. Building upon past research conducted in the Hogue research group (Kinoshita & Hogue, 2015; Saxe et al., 2016; Slinski et al., 2016), we will utilize statistical approaches to evaluate changes in annual runoff ratios, low flows, high flow, peak flows, base flow index, changes in return periods, Richards-Baker Flashiness index, and timing of the center of mass of the annual flow. To determine annual variations in discharge from the pre-treatment mean, climate elasticity models will be used to evaluate the contributions of climate and other disturbances to the observed change in discharge (Hallema et al., 2018). We will also apply time series analysis and statistical metrics to gathered sediment parameters and remote sensing data. These statistical methods have been successful in our previous research in the Ashland basin, demonstrating that at low treatment levels, climate is dominating the hydrologic response in this area (Figure 3).

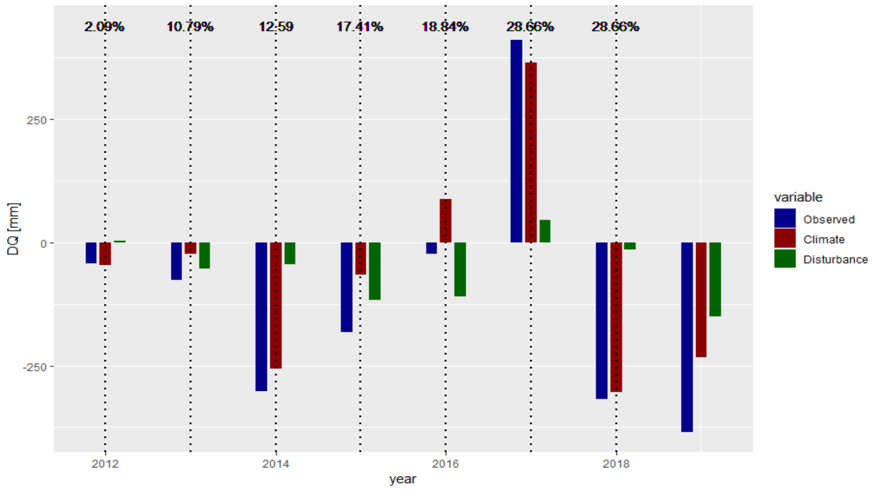

Figure 3. Climate Elasticity Model (CEM) applied to a watershed near Ashland, OR.

Additionally this collected data will be used for statistical regression and conditional inference tree analysis to determine the driving factors to predict change in discharge from upstream mitigation treatments. Discharge from the outlet of the watershed will be compared with vegetation indices to observe how the greenness signal responds to basin treatments and to determine which vegetation index is representative of hydrologic changes. Preliminary results in the Sagehen watershed demonstrate that there is no distinct trend in streamflow by treatment types. While there are some relationships between NDVI and stage, these parameters do not show a distinct response for each treatment type.

Establishing relations between forest structure change and hydrologic response for each treatment type will provide a basis for a management tool. Statistical models that can reliably predict water yield changes relative to climate and forest management will allow land and resource managers to better plan for more diverse and fire resilient forests, while also improving water yield forecasts in a critical mountain range. It is the goal to take the statistical framework above, and create an integrated statistical package in R that will allow for ecohydrologic monitoring in any desired basin. This package will include functions to calculate statistical changes in runoff ratios, seven-day minimum flows, high flows, timing of the center of mass, seasonal hydrologic regime shifts, and timing of peak flow. These metrics have been used in a range of studies to evaluate change in hydrologic systems (del Campo et al., 2018; Hallema et al., 2018; Helsel & Hirsch, 2002; Hunt et al., 2018; Podolak et al., 2015). This package will also include inference tree functions to aid in understanding what ecological functions are influencing streamflow.

The package will have a user-friendly interface that can be implemented on any operating systems (PC, MACS, etc.) and can also be easily updated with statistical metrics and data streams specific to the user's site of interest. A range of outputs will be available, including timeseries of remote-sensing and hydrologic variables, hydrographs, and statistical reports. The proposed work will also provide a method to upscale the basin results to larger areas by relating field-scale information to remote sensing products. This will improve our management of not only water quality and quantity, but also forest resiliency to natural hazards and extreme fire events of different scales.

4.5 Physically-based Hydrologic Modeling

4.5.1 Model Development

This task will focus on model development and parameterization for both basin and treatment-scale regions as well as development of scenarios to represent a range of fuel treatment options The complexity of sub-alpine environments and the tightly coupled ecohydrologic behavior complicate accurate modeling of impacts of forest structure change with traditional hydrologic models (i.e. rainfall-runoff or land surface models). Although we have used a range of these types of models as well as snow models in mountain watersheds (Hogue et al., 2006a, 2006b; Franz et al., 2008a, 2008b; He et al., 2010, 2011, 2012), we propose a more holistic approach involving a spatially explicit, physically-based hydrologic model that can consider the interactions of vegetation with hydrologic processes. In coordination with EMC, we will investigate use of different models for implementation in this project; options include the MIKE-SHE, WRF-HYDRO and the Regional Hydro-Ecologic Simulation System (RHESSys) model for the Sagehen basin. These models require meteorological inputs and distributed physical data (land cover, soils, canopy, etc.), which will be derived from previous forest studies such as Bales et al., (2011) and the current study (Section 3). Simulations (outputs) will include vertical fluxes (ET, canopy and litter interception, infiltration, drainage) and lateral movement between patches of ecosystems. A key component of this work will be to develop spatially representative vegetation parameters (through our remote sensing work above (LAI)) to represent forest structure changes for each treatment type.

4.5.2 Model Calibration

We will use sub-basin flow data from 11 sub-basins in the Sagehen watershed, with each sub-basins representing runoff from specific treatment types (or no treatment) as well as vegetation cover, soil type and slope aspect. We will initially calibrate the hydrologic model to the basin outlet using the long-term discharge data at the outlet, we will then model sub-basin response initially using the calibrated parameters at the basin outlet, and scaling values as needed for each sub-basin unit relative to the in situ observations below each treatment type.

4.5.3 Fuel Treatment and Forest Cover Scenarios

We will develop scenarios in tandem with EMC and relevant stakeholders in order to simulate the effect of cumulative and spatially variable fuel treatments on hydrologic response. We will undertake iterative discussions with these groups to develop relevant and stakeholder-driven scenarios for canopy loss and cumulative treatment conditions. The developed hydrologic model will then be used to simulate post-treatment discharge at the sub-basin resolution and at the watershed scale using these scenarios. We will also undertake synthetic simulations using a range of developed LAI timeseries to simulate potential post-treatment behavior. This can be done using a Monte Carlo approach using previous studies as a guide (McMichael et al., 2004; Tague et al., 2009). These multiple model simulations will be used to run hindcasts (historical climate) range of potential sub-basin flow conditions and the associated range of uncertainty given treatment variability. These initial post-treatment model runs (stakeholder-driven and synthetic) will also allow us to refine key model parameters that relate to forest structure change for transferring the model to regional basins for scenarios of regional change.

Finally, we plan to compare results from the developed physically-based model with the statistical model to evaluate reliability and predictive capabilities of the two approaches. We hypothesize that this will provide a better assessment of uncertainty in the two systems and help identify deficiencies or discrepancies in the statistical model and the parameterized hydrologic model.

5. Scientific Uncertainty and Geographic Application

The statistical methods used to evaluate the monitoring efforts will utilize non-parametric test to evaluate the significance of observed trends and changes. The significance will be determined by well-established methods that recognize uncertainty and will be conducted at a ninety five percent confidence interval (Helsel & Hirsch, 2002). The final packaged framework will provide the needed uncertainty bounds for decision-makers.

The developed models are applicable to Sierra Nevada watersheds and other similar hydroclimatic regimes. We expect that the models and metrics developed in this project to be readily transferred to watersheds in the vicinity of the test basin, Sagehen experimental watershed located in the northern Sierra Nevada, as well as other watersheds along both the western and eastern slopes of this mountain range. The developed models and statistical framework will allow user-input of data streams and spatial information specific to watersheds undergoing treatments and forest mitigation. Our goal is that the modeling tools and framework developed in this proposal are readily accessible and usable by a range of resource managers and stakeholders to evaluate both historical and predicted forest mitigation and treatment impacts on hydrologic response across the Sierra Nevada range.

6. Collaborations and Project Feasibility

The proposed work builds upon the PIs extensive research on understanding and predicting hydrologic behavior in altered watersheds, using ground-based observations, satellite imagery and predictive frameworks which includes a range of collaborations with local, state and regional stakeholders and resource managers (Atchley et al., 2018; Blount et al., 2019; Burke et al., 2013; Chin et al., 2019; Florsheim et al., 2017; Kinoshita & Hogue, 2011; 2015; Kinoshita et al., 2013 ; 2014; Knipper et al., 2016; Micheletty et al., 2014; Nourbakhsh-beidokhti et al., 2019; Poon & Kinoshita, 2018a; 2018b; Rust et al., 2018; 2019a; 2019b; Saxe et al., 2018; Slinski et al., 2016; Stein et al., 2012). In addition to our prior work, both project PIs have ongoing projects on forest disturbance across the western U.S. Hogue has ongoing forest-related projects in the Ashland watershed to evaluate treatments strategies on hydrologic response (funded by Oregon TNC); in Durango, Colorado, evaluating the impact of the 416 fire on water quality and in downstream ecosystems (in collaboration with Mountain Studies Institute; and a project in the upper Rio Grande watershed, evaluating the long-term impacts of the West Fork Fire complex fire on water quantity and quality and post-fire hydrologic modeling (funded by a local stakeholder group, RWEACT (https://www.rweact.org/) and the BLM Joint Fire Science Program). PI Kinoshita currently has projects focused on understanding hydrologic impacts after vegetation restoration activities and understanding the potential for contamination events in the San Diego River Watershed (supported by the San Diego River Conservancy and the City of San Diego Water Board); hydrologic modeling to support integrated land use planning for climate resilient ecosystems and local communities (numerous stakeholders and supported by the California Strategic Growth Council); understanding the impacts of fires in urban and Mediterranean streams (National Science Foundation); and improving predictions for post-wildfire streamflow (in collaboration with CGS and CalFire).

In the Sagehen basin, we build upon prior and ongoing collaborations with the Tahoe National Forest, TNC and the Bella Vista Foundation, as well as our ongoing research activities in Sagehen. We have been active in this basin since 2004 as an educational site (for UCLA courses) and as a research site since 2012, when funding was obtained by the Bella Vista foundation to support installation of a distributed network of channel stage recorders (pressure transducer) (Figure 1). The new recorders were strategically placed to capture discharge of basins varying in treatment type and geomorphic parameters (based on collaborations and discussions with the USFS). In 2015, funding was obtained from TNC ($50,000) to support travel to the Sagehen basin for data monitoring and data collection of the installed sensors. The TNC proposal focused on preliminary data collection activities and providing logistical support such as travel, equipment, and lodging. The TNC funding was utilized until this fall (September 2019) when funds were expired. As described above, funding from EMC provides a unique opportunity to continue critical post-treatment monitoring, coupling of ground-based observations with satellite imagery, rigorous statistical analysis and quantification of hydrologic response relative to treatment strategies, and development of a parsimonious, user-friendly framework that can detect and quantify change in altered forests systems and their impacts on hydrologic behavior and downstream ecosystems.

7. Project Deliverables

We expect a range of products and tools developed through this proposal. Specifically we plan to provide the following deliverables:

- Database of ground-based monitoring observations including streamflow and temperature data collected below a range of forest mitigation strategies
- Remote sensing data, both LIDAR and Landsat-based, that quantifies forest canopy structure after forest thinning and mitigation
- Physically-based hydrologic model parameterized for a range of spatially-varying fuel treatments
- Statistical tools and algorithms that integrate the monitoring data and satellite-based products and can elucidate relationships between forest canopy change and hydrologic response
- A user-friendly, integrated package, including models and statistical framework, that is downloadable and usable by stakeholders, resource managers and decision-makers
- Scientific papers and reports outlining results from this work

All products will be available for download by websites hosted by the PIs at their respective institutions. We also plan to distribute the final package/framework to interested agencies and stakeholders (EMC, USFS, TNC, etc.) for distribution to their stakeholders and relevant constituents. We will also produce scientific papers and reports that overview results and findings from this study.

8. Detailed Project Timeline

Table 1. Project Tasks and Associated Timelin**e**

Task Descriptions	June-Aug	Sept-Nov	Dec-Feb	March-May	June-Aug	Sept-Nov	Dec-Feb	March-May
Monitoring / Field Data Collection								
Field-based monitoring (discharge, cross-sections, etc.)	▨	▨	▨	▨	▨	▨	▨	▨
Vegetation observations spot-check		▨		▨		▨		▨
Collection of satellite-based data (LAI, NDVI, LIDAR)	▨	▨	▨	▨	▨	▨	▨	
Data Analysis and Synthesis								
Statistical analysis of individual data streams			▨	▨	▨	▨	▨	
Integration/models of satellite and ground-based data			▨	▨	▨	▨	▨	
Framework / Tool Development								
Integration of R pacakages				▨	▨	▨	▨	▨
Framework / GUI development / Testing						▨	▨	▨
Physcially-based Modeling								
Model Selection, parametreization and calibraiton	▨	▨	▨	▨	▨			
Scenario development and relevant predictions				▨	▨	▨	▨	▨
Outreach and Dissemination								
Project Updates from the field				▨				▨
AGU Fall Annual Meeting			▨				▨	
Annual Reports				▨				▨
Final Report and Documentation								▨
Dissemation of tool to EMC and stekholders								▨
Scientific Papers				▨				▨

9. Requested Funding

We are requesting $156,665 in funding for the two years of proposed work under this project. This total includes $81,887 to Colorado School of Mines (lead) and $74,788 to San Diego State University (subaward through CSM). IDC total for the proposal is $23,276 (14.8% of total costs). A detailed budget and relevant documents are included with this proposal.

PIs Hogue and Kinoshita are uniquely qualified to undertake the proposed work. They have extensive experience in monitoring and predicting disturbance hydrology and have a history of engagement with local and regional stakeholders and managers that results in usable decision-making tools and data products.

PI Hogue will be primarily responsible for monitoring of the ground-based observations at Sagehen, including discharge, geochemistry, stream temperature, channel cross sections for rating curves, and other related data. PI Hogue will also be lead on integration of data products (including those from SDSU), relevant statistical analysis, model development and creation of the R-package framework that will be developed for stakeholders. Hogue will also be responsible for budget oversight, annual and final reporting, and communication and outreach with EMC. PI Kinoshita will supervise the workplan at SDSU to acquire 1) treatment maps and delineations; 2) leaf area index (LAI); and 3) pre- and post-treatment Light Detection and Ranging (LiDAR) remote sensing data. PI Kinoshita will be primarily responsible for preparing, processing, analyzing, and synthesizing the LAI and LiDAR data. She will also serve as lead for communications between SDSU and CSM and will collaborate with CSM to complete field work and to develop a framework to provide a science-based management tool.

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Research Interests

Urbanization and sustainability, catchment response to wildfire, climate variability and watershed response, modeling of watershed and snowmelt processes, development and application of remote sensing products.

Professional Preparation

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University of Arizona, Tucson, AZ	M.S. Hydrology and Water Resources	Dec. 1998
University of Arizona, Tucson, AZ	Ph.D. Hydrology and Water Resources	May 2003

Appointments

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Professor, CEE Department, Colorado School of Mines, July 2015-present
Director, Hydrologic Sciences and Engineering Program, CSM, August 2014-Dec. 2017
Associate Professor, Colorado School of Mines, CSM, July 2012-June 2015
Vice Chair for Undergraduate Affairs, CEE Department, CSM, October 2012-August 2014
Associate Director, Hydrologic Sciences and Engineering Program, CSM, July 2012-present
Associate Professor, University of California, Los Angeles, July 2009-June 2012
Assistant Professor, University of California, Los Angeles, July 2003-June 2009
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Relevant Publications:

1. Blount, W.K., C. Ruybal, K. Franz and **T.S. Hogue**, 2019: Increased water yield and altered water partitioning follow wildfire in a forested catchment in the western U.S., *Ecohydrology* (in press)
2. Rust, A.J., J. Randell, A. Todd, and **T S. Hogue**, 2019: Wildfire Impacts on Water Quality, Insect, and Trout Populations in the Upper Rio Grande, *Forest Ecology and Management*, https://doi.org/10.1016/j.foreco.2019.117636
3. Rust, A.J., S Saxe, J. McCray, C. C. Rhoades, and **T.S. Hogue**, 2019: Evaluating the Factors Responsible for Post-Fire Water Quality Response in Forests of the Western USA, International Journal of Wildland Fire, https://doi.org/10.1071/WF18191
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10. Knipper, K., **T.S. Hogue**, and A. Kinoshita, 2016: Evaluation of a MODIS Triangle-based Algorithm for Evapotranspiration Estimates in Sub-alpine Regions, *Journal of Applied Remote Sensing*, 10(1), 16002, 1-20, DOI: 10.1117/1.JRS.10.016002.
11. Knipper, K., **T.S. Hogue**, K. Franz and R. Scott, 2017: Evapotranspiration Estimates Derived Using Multi-Platform Remote Sensing in a Semiarid Region, *Remote Sens. 9*(3), 184; doi:10.3390/rs9030184.
12. Micheletty, P.D., A.M. Kinoshita, and **T.S. Hogue,** 2014: Application of MODSCAG and MODIS snow cover products in post-fire watersheds in the Sierra Nevada, *Hydrology and Earth System Science*, 18, 4601-4615.
13. Burke, M., **T.S. Hogue**, A. Kinoshita, J. Barco, C. Wessel, and E. Stein, 2013: Pre- and Post-fire Pollutant Loads in an Urban Fringe Watershed in Southern California, *Environmental Monitoring and Assessment*, 10.1007/s10661-013-3318-9.
14. Stein, E.D, J. S. Brown, **T. S. Hogue**, M. P. Burke, and A. Kinoshita, 2012: Regional Patterns of Storm Water Contaminant Loading Following Southern California Wildfires, *Environmental Toxicology and* Chemistry, 31 (11), 2625-2638.

Synergistic Activities:

AGU Water Resources Research Editorial Board (April 2017-April 2018)
Colorado School of Mines Board of Trustees Member (Jan 2017-Dec. 2018)
National Academies Decadal Survey Panel Member, (May 2016-May 2018)
National Academies Board on Atmospheric Science and Climate (Oct. 2013-present)
AGU Council Task Force on Science Trends (April 2014-Aug. 2015)
American Geophysical Union Hydrology Section Secretary (Jan. 2013-Dec. 2016)
AGU Surface Water Committee, Chair (2010-2012); Deputy Chair (2008-2010)
NSF Hydrologic Sciences Program Proposal Panels (2010-present)
NSF EPSCoR Review Panel and Wyoming WyCHEG site review (2013, 2016)

Advisees

- Graduated 17 PhD students, 20 MS Thesis, and mentored 6 post-doctoral fellows
- Currently supervising 9 PhD students and 4 post-doctoral fellows
- Mentored over 40 undergraduate researchers and scholars

Alicia M. Kinoshita

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San Diego State University, 5500 Campanile Drive, San Diego CA, USA 92182

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Website: http://sdsu-dhl.weebly.com/

A. Professional Preparation

University of California, Los Angeles (UCLA)	Civil Engineering	B.S., 2007
University of California, Los Angeles	Civil Engineering	M.S., 2009
University of California, Los Angeles	Civil Engineering	Ph.D., 2012
Colorado School of Mines (CSM)	Civil Engineering	Postdoctoral Fellow, 2012-2014

B. Appointments

2019 – present	Associate Professor, Civil, Construction, & Environmental Engineering San Diego State University
2014 – 2019	Assistant Professor, Civil, Construction, & Environmental Engineering San Diego State University

C. Products

(i) Five publications most closely related to the proposed project (*indicates SDSU advisee)

1. **Kinoshita, A.M.,** and T.S. Hogue, 2011: Spatial and Temporal Controls on Post-fire Hydrologic Recovery in Southern California Watersheds, *Catena*, 87, 240-252.
2. **Kinoshita A.M.** and T.S. Hogue, 2015: Increased Dry Season Water Yield in Burned Watersheds in Southern California. *Environmental Research Letters*, 10(1).
3. Florsheim, J.L., A. Chin, **A.M. Kinoshita**, S. Nourbakshbeidokhti*, 2017: Effect of storms during drought on post-wildfire recovery of channel sediment dynamics and habitat in the southern California chaparral, USA. *Earth Surface Processes and Landforms*.
4. Nourbakhsh-beidokhti, S., **A.M. Kinoshita**, A. Chin, J.L. Florsheim, 2019: A Workflow to Estimate Topographic and Volumetric Changes and Errors in Channel Sedimentation after Disturbance. Remote Sensing, 11(5), p.586.
5. Chin, A., A.P. Solverson, A.P, O'Dowd, J.L. Florsheim, **A.M. Kinoshita**, S. Nourbakhsh-beidokhti*, S.M Sellers, L. Tyner, and R. Gidley, 2019. Interacting geomorphic and ecological response of step-pool streams after wildfire. Geological Society of America Bulletin.

(ii) Five other relevant and significant publications

1. Knipper, K. R., **Kinoshita, A. M.**, and Hogue, T. S., 2016: Evaluation of a moderate resolution imaging spectroradiometer triangle-based algorithm for evapotranspiration estimates in subalpine regions. Journal of Applied Remote Sensing,
2. Micheletty, P.D., **A.M. Kinoshita**, T.S. Hogue, 2014: Application of MODIS snow cover products: Wildfire impacts on snow and melt in the Sierra Nevada. *Hydrology and Earth System Sciences*, 18, 4601-4615.
3. Poon, P.K.*, **A.M. Kinoshita**, 2018. Spatial and temporal evapotranspiration trends after wildfire in semi-arid landscapes. *Journal of Hydrology*. Landforms.
4. Stein, E.D, J.S. Brown, T.S. Hogue, M.P. Burke, and **A. Kinoshita**, 2012: Stormwater contaminant loading following southern California wildfires, *Environmental Toxicology and Chemistry*, 31(11), 2625-2638.
5. Burke, M.P., T.S. Hogue, **A.M. Kinoshita**, J. Barco, C. Wessel, and E. Stein, 2013: Pre- and Post-fire Pollutant Loads in an Urban Fringe Watershed in Southern California. *Environ Monit Assess.*

D. Synergistic Activities

1. **Principle Investigator:** CAREER: Coupling post-fire vegetation and volumetric sediment regimes in urban Mediterranean systems, National Science Foundation (NSF) Faculty Early Career Development Program, 06/01/2019-05/31/2024, current award ($571,796). The goal of this research is to understand and predict changes in vegetation, soil, and stream processes that occur after fires using remote sensing and field methods. This work will also increase community education opportunities and interactions through public seminars and outreach events.

2. **Lead Senior Personnel for Water Sustainability:** Integrated land use planning to support climate resilient ecosystems and local communities: planning for fire risk, water sustainability, and biodiversity, California Strategic Growth Council Climate Change Research Program, 10/1/2018-03/30/2021, current award ($1,790,000). This project utilizes funding to form a diverse partner network on developing an integrated land-use planning approach to protect rural communities, mitigate wildfire risk, support water sustainability, and protect biodiversity.

3. **Student Advising and Mentoring at SDSU**. Four M.S. Thesis Advisor and Chair (I. Crano; A. Mirhosseini; P. Poon; S. Nourbakhshbeidokhti); seven M.S. thesis currently advised; and over fifteen undergraduate students advised.

4. **Fellow, Center for Research, Excellence, and Diversity in Team Science, 2016**. *Living with Climate Change*, UCLA Lake Arrowhead Conference Center in Lake Arrowhead, CA.

5. **Burned Area Emergency Response (BAER) Hydrologic Modeling Training Workshop, 2011.** Bureau of Land Management BAER National Meeting, Lakewood, CO, June 7, 2011. This workshop was organized and led by A.M. Kinoshita and T.S. Hogue.

Proposed Budget
June 1, 2020 - May 31, 2022

			Year 1	Year 2	Total
A.	SALARIES AND WAGES				
	1.	Terri Hogue, PI - 1 summer day	$991	$1,021	$2,012
	2.	1 Graduate Research Assistant - 8 AY months @ 50%	12,000	12,360	24,360
		Subtotal	$12,991	$13,381	$26,372
B.	FRINGE BENEFITS				
	1.	42.2%* of A1	$418	$438	$856
	2.	GRA tuition, fees, health ins. - 2 semesters/reduced tuition	11,948	12,425	24,374
		Subtotal	$12,366	$12,864	$25,229
C.	OTHER DIRECT COSTS				
	1.	Travel - Travel to Sagehen (domestic)			
		3 trips/year; 2 people, $1000/trip	$3,000	$3,000	$6,000
	2.	Expendable field supplies	500	500	1,000
	3.	Subcontract: South Dakota State University	37,350	37,438	74,788
		Subtotal	$40,850	$40,938	$81,788
D.	TOTAL DIRECT COSTS		$66,207	$67,182	$133,389
E.	MODIFIED TOTAL DIRECT COSTS**		$41,910	$17,319	$59,229
F.	INDIRECT COSTS - 39.3% of E***		16,471	6,806	23,276
G.	**TOTAL AMOUNT REQUESTED**		**$82,677**	**$73,989**	**$156,665**

*rate increases .67 annually
**Line D not including B2 or subcontract costs C3 exceeding $25,000

BUDGET JUSTIFICATION
Terri S. Hogue
Colorado School of Mines

PERSONNEL COSTS:

Dr. Terri Hogue will be responsible for overseeing the research at the Colorado School of Mines (CSM) under this grant. Dr. Hogue will be responsible for supervision of the graduate student, Jake Kurzweil. PI Hogue will be primarily responsible for monitoring of the ground-based observations at Sagehen, including discharge, geochemistry, stream temperature, channel cross sections for rating curves, and other related data. PI Hogue will also be lead on integration of data products (including those from SDSU), relevant statistical analysis and development of the R-package framework that will be developed for stakeholders. Hogue will also be responsible for budget oversight, annual and final reporting, and communication and outreach with EMC. The graduate student will work with Dr. Hogue on this project and will undertake field monitoring, data analysis and framework development.

Salaries and wages have been calculated on the basis of the Colorado School of Mines Policies. Employee benefits have been estimated using the current federal rate agreement, including 42.2% for the PI and graduate tuition, fees and health insurance for the graduate student.

OTHER DIRECT COSTS

Projected costs in this category are based on historical data for projects of similar scope. Expendable field supplies are estimated at $500/year for CSM on this project.

TRAVEL

Funds are requested for the PI and graduate student to travel to the field site 3x/year. Approximate costs of $500 per person per trip includes airfare, lodging, rental car and per diem costs.

Indirect Costs (Facilities & Administrative Costs)

The indirect costs are estimated at just under 15% of total direct costs in accordance with the EMC overhead rate agreement for these proposals.

Title / Agency Name / Solicitation Number
Dr. Alicia Kinoshita
Project Dates

												1.03	
		Key Indicators								**YEAR 1**	**YEAR 2**	**TOTAL**	
A & B. PERSONNEL		**Key**	**Type**	**Salary Sched.**	**Base**	**Monthly**	**# of Mos**	**FTE**	**Person Months**				
1	PI: Alicia Kinoshita	X	AY	10291	$ 123,492	$ 13,721	9	0.00%	0.00	$ -	$ -	$ -	
			SU	10291	$ 41,164	$ 13,721	3	5.00%	0.15	$ 2,058	$ 2,120	$ 4,178	
									subtotal	*$ 2,058*	*$ 2,120*	*$ 4,178*	
	PI fringe benefits*		AY		57.4%					$ -	$ -	$ -	
			SU		25.0%					$ 515	$ 530	$ 1,045	
									subtotal	*$ 515*	*$ 530*	*$ 1,045*	
2	Co-PI		AY		$ -	$ -	9	0.00%	0.00	$ -	$ -	$ -	
			SU		$ -	$ -	3	0.00%	0.00	$ -	$ -	$ -	
									subtotal	*$ -*	*$ -*	*$ -*	
	Co-PI fringe benefits*		AY		57.4%					$ -	$ -	$ -	
			SU		25.0%					$ -	$ -	$ -	
									subtotal	*$ -*	*$ -*	*$ -*	
3	Program Director		CY		$ -	$ -	12	0.00%	0.00	$ -	$ -	$ -	
	Prog Dir fringe*		CY		46.0%					$ -	$ -	$ -	
4	Graduate Student	1	AY	19	$ 29,639	$ 3,293	9	50.00%	4.50	$ 14,820	$ 14,820	$ 29,640	
	Graduate Student	1	SU	19	$ 9,880	$ 3,293	3	100.00%	3.00	$ 9,880	$ 9,880	$ 19,760	
									subtotal	*$ 24,700*	*$ 24,700*	*$ 49,400*	
	Grad Student fringe*				15.0%					$ 3,705	$ 3,705	$ 69,160	
									Total Salaries	*$ 26,758*	*$ 26,820*	*$ 53,578*	
*rates reflect 3% escalation									**Total Fringe Benefits**	*$ 4,220*	*$ 4,235*	*$ 8,455*	
									TOTAL PERSONNEL	**$ 30,978**	**$ 31,055**	**$ 62,033**	
C. EQUIPMENT													
1										$ -	$ -	$ -	
2										$ -	$ -	$ -	
									TOTAL EQUIPMENT	**$ -**	**$ -**	**$ -**	
D.TRAVEL													
1	Domestic Travel									$ 1,500	$ 1,500	$ 3,000	
2	International Travel									$ -	$ -	$ -	
									TOTAL TRAVEL	**$ 1,500**	**$ 1,500**	**$ 3,000**	
E. PARTICIPANT/TRAINEE SUPPORT COSTS (NIH - ONLY if specifically allowed by your PA/PAR/RFA)													
1	Tuition/Fees/Health Insurance									$ -	$ -	$ -	
2	Stipends									$ -	$ -	$ -	
3	Travel									$ -	$ -	$ -	
4	Subsistence									$ -	$ -	$ -	
5	Other									$ -	$ -	$ -	
									TOTAL PARTICIPANT COSTS	**$ -**	**$ -**	**$ -**	
F. OTHER DIRECT COSTS													
1	Materials and Supplies									$ -	$ -	$ -	
2	Publication Costs									$ -	$ -	$ -	
3	Consultant Services									$ -	$ -	$ -	
4	ADP/Computer Services									$ -	$ -	$ -	
5	Subawards/Consortium/Contractual Costs								**direct costs**	$ -	$ -	$ -	
									F&A	$ -	$ -	$ -	
6	Equipment or Facility Rental/User Fees									$ -	$ -	$ -	
7	Alterations and Renovations									$ -	$ -	$ -	
8	Other 1									$ -	$ -	$ -	
9	Other 2									$ -	$ -	$ -	
10	Other 3								**TOTAL OTHER DIRECT COSTS**	**$ -**	**$ -**	**$ -**	
TOTAL DIRECT COSTS										**$ 32,478**	**$ 32,555**	**$ 65,033**	
TOTAL MODIFIED DIRECT COSTS										**$ 32,478**	**$ 32,555**	**$ 65,033**	
F&A @ MTDC*				**15.00%**						**$ 4,872**	**$ 4,883**	**$ 9,755**	**Per Sponsor Indirect Not to Exceed 15%**
TOTAL PROJECT COSTS										**$ 37,350**	**$ 37,438**	**$ 74,788**	

Excludes equipment over $5K, capital expenditures (A&R), patient care, tuition remission, rental costs of off-site facilities, scholarships & fellowships, and Limited to the first $25K of each subcontract

NIH policy provides for exclusion of consortium/contractual F&A when determining if an applicant is in compliance with a direct cost limitation. This policy extends to all applications involving consortium/contractual facilities and administrative (F&A) costs, regardless of budget amount or budget format (e.g., modular and non-modular).

	YEAR 1	YEAR 2	TOTAL
TOTAL NIH DIRECT COSTS MINUS SUBCONTRACTOR F&A	**$ 32,478**	**$ 32,555**	**$ 65,033**

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SDSU Budget Justification

The budget includes:

1. Salary and benefits for 0.5 month summer salary for Co-PI Alicia Kinoshita for two years ($4,178 salary plus $1,045 fringe benefits based on the current benefit rate of 25%). Salary will support Kinoshita to supervise the workplan at SDSU to acquire 1) treatment maps and delineations from CSM; 2) leaf area index (LAI) since 2012 through current for Sagehen from remote sensing hosting platforms and 3) pre- and post-treatment Light Detection and Ranging (LiDAR) remote sensing data for Sagehen from OpenTopography. Kinoshita will supervise her graduate student in preparing, processing, and analyzing the relevant remote sensing data and two field reconnaissance trips per year. She will also serve as lead for communications between SDSU and CSM and will collaborate with CSM to develop a framework to provide a science-based management tool primarily in Year 2.

1) Salary and benefits for 1 graduate student for two years ($49,400 salary plus $7,410 fringe benefits based on the current benefit rate of 15%). Salary requested will support a graduate student to acquire remote sensing products (LAI and LiDAR), prepare and process the data, analyze the information with respect to treatments and in collaboration with CSM vegetation products. The graduate student will also be supported to participate in 2 field site visits per year to corroborate remote sensing results. They student will also be engaged in developing a framework with CSM.

2) Travel for the Co-PI and student to the field site for two years ($3,000)
It is estimated that roundtrip flight from San Diego to Reno is ~$300/person/trip (based on previous trip to the field site in 2016) plus $80/person /trip for meals and incidentals (total of ~$760/trip). For two trips to the field site in Year 1, the total is anticipated to be ~$1,500 for the PI and student. For Year 2, the total is anticipated to be ~$1,500 for the PI and student.

3) F&A calculated at the rate allowable by EMC for this proposal agreement ($9,755 at 15%).