Project #: EMC-2018-006

Project title: Effectiveness of Class II Watercourse and Lake Protection Zone (WLPZ) Forest Practice Rules (FPRs) and Aquatic Habitat Conservation Plan (AHCP) Riparian Prescriptions at Maintaining or Restoring Canopy Closure, Stream Water Temperature, Primary Productivity, and Terrestrial Habitat

PIs: Kevin Bladon, Catalina Segura, Matt House, Drew Coe, Nicholas Simpson

Collaborators: Oregon State University, Green Diamond Resource Company, CALFIRE, California Department of Fish and Wildlife

Critical Question Themes and Rules or Regulations being Tested: Theme 1: WLPZ Riparian Function

Timeline: The duration of the project will be 4 years starting June 1, 2019 and continuing until May 31, 2023 (Table 1). The timeline presented in Table 1 indicates the core activities associated with each of the main data collection components of the research.

1. Background and justification

Estimating the thermal response of headwater streams and rivers to forest management activities is increasingly important given current and projected climate change (Luce et al., 2014; Pyne and Poff, 2017) and increasing land use activities (Hester and Doyle, 2011). Historical forest management activities, such as harvesting near streams, often resulted in increased summertime stream temperatures because of reduced shade and increased solar radiation reaching the stream surface (Moore and Wondzell, 2005; Studinski et al., 2012). Changes in stream temperature regimes are principally a concern when resulting temperatures are outside the range of thermal tolerances for aquatic ecosystem biota (Dunham et al., 2003; Bear et al., 2007). Elevated stream temperatures can affect primary productivity (D’Angelo et al., 1997; Morin et al., 1999), benthic invertebrates (Hogg and Williams, 1996; Hawkins et al., 1997; Caruso, 2002), fish habitat (Eaton and Scheller, 1996; Beiting, 2000; Waite and Carpenter, 2000; Ice, 2008), as well as the rates of in-stream chemical processes (Demars et al., 2011).

To address and mitigate negative impacts from forest harvesting activities in and around riparian zones, best management practices (BMPs) have been developed and implemented (Cristan et al., 2016). In particular, BMPs aimed at maintenance or reestablishment of streamside forests have been effective at improving many of the functions of riparian zones. For example, there is strong evidence that riparian forests have been effective at providing shade, limiting direct solar radiation to the stream, and mitigating changes in stream temperature after contemporary forest harvesting (McGurk, 1989; Ledwith, 1996; Bladon et al., 2016; Bladon et al., 2018). Maintenance of shade has been found to be an effective strategy to mitigate stream temperature changes following forest harvesting as direct solar radiation and atmospheric conditions...
are often the primary driver for summer stream temperatures (Cafferata, 1990; Sinokrot and Stefan, 1993; James, 2003; Johnson, 2004; Wick, 2016). There is recent evidence, though, that too much shade from riparian forests may reduce in-stream photosynthesis (primary productivity) with associated declines in aquatic insects, fish, and/or amphibian productivity (Wilzbach et al., 2005; Newton and Ice, 2016). Additionally, there is some evidence that other factors, such as stream orientation (Gomi et al., 2006), steepness of channel slopes (Kasahara and Wondzell, 2003), and the contributions to streamflow from groundwater or hyporheic exchange (Moore and Wondzell, 2005) could all influence the effectiveness of riparian zones. However, the relative importance of these different factors and the possible tradeoffs in riparian function haven’t been adequately or holistically examined.

The California Forest Practice Rules (FPRs) specify regulations for operations within Watercourse Lake and Protection Zones (WLPZs), the strips of retained trees and/or vegetation, along both sides of a watercourse. As an alternative to the ASP FPRs, private landowners may also develop tailored riparian prescriptions within an Aquatic Habitat Conservation Plan (AHCP), as part of the application for an Incidental Take Permit (ITP). For example, Green Diamond Resource Company (GDRC) has had an approved AHCP since 2007, which includes specific requirements for Class II watercourses. The AHCP also includes monitoring and a process to iteratively adjust management practices in response to findings from monitoring and experiments (i.e., adaptive management). In either case, these forest management practices are designed to ensure that “timber operations do not potentially cause significant adverse site-specific and cumulative impacts to the beneficial uses of water, native aquatic and riparian-associated species, and the beneficial functions of riparian zones” (CAL FIRE, 2017). As such, both the ASP FPRs and GDRC AHCP Class II riparian requirements for the WLPZ have the potential to contribute toward the objectives of key policies, such as the federal Endangered Species Act, California Endangered Species Act, Clean Water Action Section 303(d), Salmon Policy, Water Policy, and Joint Pacific Salmon and Anadromous Trout Policies (CAL FIRE, 2017). However, again, the effectiveness of current WLPZ regulations have not been thoroughly examined.

The effectiveness of current WLPZ regulations at mitigating adverse site-specific and cumulative impacts are particularly important in Class II-L (Large) watercourses. In California, the Forest Practice Rules (FPRs) afford the most protection to Class I (fish bearing) relative to Class II (aquatic life other than fish) and Class III streams (not supporting aquatic life). However, it has been recognized that headwater systems can be critically important to the water quality in downstream sites (MacDonald and Coe, 2007). This has led to the establishment of stricter provisions for Class II Large (Class II-L) watercourses compared to other Class II Standard (Class II-S) streams, according to the “Anadromous Salmonid Protection Rules, 2009” (ASP), and modified by the “Class II-L Identification and Protection Amendments, 2013” rule package approved by the California State Board of Forestry and Fire Protection in October, 2013. At present, the regulations require a 30 foot core zone and a 70 foot inner zone within watersheds of the coastal anadromy zone (Table 1), unless a site-specific riparian prescription is approved under CCR § 916.9(v). One of the objectives of these rules is to protect anadromous salmonid habitat by minimizing potential increases in water temperature and sediment from Class II and Class III watercourses draining into Class I systems. In
addition, all watercourse and lake protection rules are designed to maintain, protect, and/or restore riparian-associated species, including amphibians and terrestrial wildlife species.

2. Objectives and scope

The broad objectives of the proposed research are to address critical questions associated with the high priority thematic area (EMC Strategic Plan Theme 1-WLPZ Riparian Function (Effectiveness Monitoring Committee, 2018) related to watercourse and lake protection zones (WLPZ) of Class II-L watercourses in the Coast District (See 14 CCR § 916.9 [936.9,956.9] (c) (4)):

a) How do the current FPRs and GDRCs AHCP Class II riparian requirements influence important controls on water quality and stream metabolism, including canopy closure, solar radiation, and near-stream air temperature during the summer low flow period?

b) What is the relative importance of the different drivers (objective a) in influencing the variability in stream temperature dynamics (e.g., maximum, minimum, diurnal variations), dissolved oxygen, and primary productivity during summer low flow across different Class II WLPZ prescriptions?

c) Integrate the data from objectives (a) and (b) to develop a model to improve understanding of the effectiveness of different Class II WLPZ prescriptions at mitigating undesirable changes in stream temperature and primary productivity following forest harvesting activities across a range of scenarios.

3. Critical questions and Relevant Forest Practice Regulations (Please address the critical question, scientific uncertainty, geographic application, and collaboration & feasibility. See the EMC Strategic Plan Appendix F for more info)

Critical Questions: The proposed project will directly contribute knowledge to the following EMC Strategic Plan Themes and Critical Questions:

- Theme 1: WLPZ Riparian Function. Specifically, the proposed research will address critical questions within this theme regarding, 'Are the FPRs and associated regulations effective in:
  (a) maintaining and restoring canopy closure?
  (b) maintaining and restoring stream water temperature?
  (d) retaining conifer and deciduous species to maintain or restore riparian shade, water temperature, and primary productivity?
  (f) maintaining and restoring riparian function of Class II-L watercourses in the Coast District?
Please see section 4. ‘Research Methods’ of this proposal for details on the study design and methods we plan to use to adequately address the proposed critical questions.

While the proposed project will not directly address the following, it is important to note that the data from the proposed project could be used to indirectly support and/or provide base data for future research on the following EMC Strategic Plan Themes and Critical Questions:

- **Theme 1: WLPZ Riparian Function. (c)** Are the FPRs and associated regulations effective in retaining predominant conifers in WLPZs (Implementation and Compliance) and large woody debris input to watercourse channels?
- **Theme 5: Fish Habitat. (b)** Are the FPRs and associated regulations effective in maintaining and restoring the distribution of foraging, rearing and spawning habitat for anadromous salmonids?
- **Theme 8: Wildlife Habitat Seral Stages. (a)** Are the FPRs and associated regulations effective in retaining and recruiting late and diverse seral stage habitat components in WLPZs for wildlife?

**Scientific Uncertainty:** The effectiveness of current WLPZ regulations at mitigating adverse site-specific and cumulative impacts are particularly important in Class II-L (Large) watercourses. Moreover, interactions between riparian conditions, light levels reaching streams, physical and chemical water quality, and primary productivity are critical knowledge gaps needed to manage riparian zones effectively. However, WLPZ regulations in the state have evolved rapidly. As such, there remains large gaps in our knowledge about the critical functions of WLPZ (additional details in section 1 ‘Background and justification’ of this proposal) necessary to maintain or enhance water quality, aquatic habitat, and wildlife habitat.

**Geographic Application:** Research results will be directly relevant and applicable to the Coast Forest District within the Coastal Anadromy Zone (CAZ), which is a sub-region covered by the Anadromous Salmonid Protection (ASP) Rules. Increased process-based understanding may also inform current knowledge gaps and future research needs in the North Forest District of the CAZ, Southern Subdistrict of the CAZ, the Current Listed Salmonid Range outside of the CAZ, and more broadly to WLPZs outside of the ASP.

**Collaboration:** The proposed project will be a multidisciplinary (e.g., foresters, hydrologists, geomorphologists, fish and wildlife ecologists) effort, involving individuals from academic, state agencies, and private industry. Base data (e.g., riparian stand structure) will be made available to collaborators to facilitate related research (e.g., large wood, terrestrial habitat), which has been discussed but is not part of this proposal.
4. Describe Research Methods

To fulfill the objectives of this study we will implement a Before-After Control-Impact (BACI) study design on GDRC holdings in the coastal anadromy zone (CAZ). We have identified 26 potential Class II-L stream reaches on GDRC holdings, which could be used for this study (Figures 1 and 2). Specifically, we have identified 17 potential stream reaches to be harvested and 6–9 potential reference stream reaches that will remain unharvested through the duration of the study. Our target, is to instrument 18 stream reaches, which would include 4 replicates of 3 WLPZ prescriptions (12 harvested stream reaches), plus 6 references streams. Specifically, the WLPZ prescriptions would include, but are not limited to: (a) ASP Coastal Anadromy Zone Class II-L Prescription – 30 foot core zone; 70 foot inner zone with 80 percent overstory canopy cover, (b) GDRC Habitat Conservation Plan (HCP) Prescription – 30 foot inner zone with 85 percent overstory canopy; 70 foot outer zone with 70 percent overstory canopy cover, and (c) alternative prescription resembling pre-ASP prescription – 100 foot zone with 50 percent overstory canopy. In the following subsections, we provide additional details about the methods we plan to use to adequately address the proposed critical questions.

4.1 WLPZ stand structure and canopy closure

We will collect pre- and post-treatment data on WLPZ stand structure from ~5–7 fixed area plots along each of the 12 prescription and 6 reference stream reaches (~90–126 plots total). Fixed area plots will be approximately 1/10 acre (~400 m²). Data will be collected on all standing live and dead trees with diameters ≥ 4 inches (>10 cm) at breast height [4.5 ft (1.37 m) above ground] that are within the WLPZ. We will record the following data for each tree: condition (live or dead), species, diameter at breast height (DBH), distance and azimuth from plot center. The canopy class (overstory, understory, or open) will be recorded for all live trees. Data recorded for dead trees includes decay class and mortality agent (e.g., wind, erosion, suppression, fire, insects, disease, and physical damage) when it is possible to determine. This foundational data is necessary to determine characteristics of the WLPZ likely to control its effectiveness and to interpret other data from this study.

The WLPZ prescriptions will be implemented to meet the specified retention requirements for canopy cover. We will use hemispherical photography to relate canopy cover requirements to canopy closure, and assess effectiveness of the WLPZ at influencing solar radiation transmission to the stream. Hemispherical photographs will be taken over the center of the stream along all reaches in the study to adequately characterize the entire WLPZ in all stream reaches (~5–7 per stream reach; ~90–126 total). All photographs will be taken vertically up into the canopy from directly over the stream with a Nikon D7100 equipped with a Sigma 45 mm f2.8 circular fisheye lens. Photographs will be taken following the recommended standard protocols for exposure, leveling, and image processing (Beckschäfer et al., 2013; Glatthorn and Beckschäfer, 2014; Origo et al., 2017). The resulting photographs record the sky visible through gaps in the forest canopy, as well as the structure of the canopy (e.g., LAI). We will use these features of the photographs to estimate solar radiation transmitted through (or
intercepted by) the WLPZ, which would then be received at the stream surface (Gonsamo et al., 2011).

Plot inventory information will be entered into the United States Forest Service’s (USFS) Forest Vegetation Simulator (FVS). FVS is a distance-independent, individual tree forest growth model developed by the USFS that has been used to project forest stand development in the Pacific Northwest (Pollock and Beechie, 2014). Extensive information regarding FVS can be found at www.fs.fed.us/fmsc/fvs/. The Pacific Northwest variant will be used. Metrics which will be evaluated through the model over a 200 year period will be average tree diameter, stand density, height, and deadwood density.

4.2. Stream temperature measurements

Stream temperature is a critical physical water quality parameter that governs in-stream processes such as metabolism, gas solubility (e.g., DO), organic matter decomposition, with potentially related effects on stream biota (Johnson, 2004). As such, we will measure stream temperature ($T_s$) along each stream reach using thermistors (Onset TidbiT v2 Water Temperature Data Logger) programmed to collect data at 30-minute intervals. We will pair stream temperature ($T_s$) loggers with air temperature ($T_a$) data loggers to develop direct, local relationships between $T_s$ and $T_a$. All in-stream loggers will be placed along the thalweg in riffle sections (avoiding stagnant pools) of each of the 12 streams in the treated watersheds and 6 reference watersheds (~8–12 loggers per stream) (Figure 3). Analytically, we will test for differences in stream temperature dynamics (e.g., maximum, minimum, mean, diurnal variations) across the different WLPZ prescriptions, which will provide critical insights into WLPZ effectiveness. Moreover, we will investigate variations in longitudinal stream temperature in all study reaches. This aspect of the study may be leveraged to provide broader insights beyond the Coast District. This will be achieved by comparing and contrasting the data we will collect with data currently being collected at the Jackson and LaTour Demonstration State Forests (since 2017) as part of a previously funded EMC project (“Multiscale investigation of perennial flow and thermal influence of headwater streams into fish bearing systems”).

4.3. Primary productivity

Primary productivity is a critical component of aquatic ecosystems, providing food for invertebrates, thus supporting salmonid production. Primary productivity is influenced by stream temperature, light levels reaching streams, and nutrient availability (Morin et al., 1999; Kiffney and Bull, 2000). However, it remains uncertain how riparian conditions influence these potential drivers and, therefore, in-stream primary productivity.

To address critical questions related to this uncertainty, we will quantify summer stream periphyton. Specifically, we will measure benthic algal biomass with a BenthotoTorch (BBE Moldaenke; http://www.bbe-moldaenke.de) at each of the stream temperature locations. The BenthotoTorch is a hand-held, fluorimeter that estimates in situ chlorophyll-a (chl-a) concentrations from the stream substrate based on absorbance of
fluorescent light (Kahlert and McKie, 2014). Chl-a is the dominant photosynthetic pigment of benthic algae in streams, so it provides an approximate estimate of primary productivity (Gregory, 1980). We will collect measurements at 3–5 replicate locations randomly selected around each stream temperature sensor (~648–1080 total).

Field measurements with the BenthoTorch will be compared against the standard brush sampling/ethanol extraction/spectrophotometric analysis method to assess the accuracy and comparability of the different measurement techniques (Marker et al., 1980; Nusch, 1980). Locations near the BenthoTorch sites will be selected randomly; sample rocks will be covered with a cap of similar diameter to the measurement surface of the BenthoTorch (3 cm vs 1 cm for the cap and BenthoTorch respectively). The cap will remain in place while the remainder of the rock will be scrubbed with a nylon brush and rinsed. Following the rinsing procedure, the cap will be removed and the area below will be scrubbed vigorously with a nylon brush. This procedure will be repeated two additional times to collected a composite sample. The removed material from the small diameter sampling surface will be placed into a 250 mL bottle and topped off to 250 mL with stream water. The samples will be kept cold prior to transport to the laboratory. In the laboratory, the samples will be filtered in the dark (0.7 μm glass fiber filters). Filters will be stored in centrifuge tubes at -20°C for 18 days prior to extraction using sonication and hot 95% ethanol. Chl-a concentrations of the extractant will measured using a spectrophotometer and not corrected for phaeophytin as the BenthoTorch cannot distinguish between photoactive pigments.

While the in situ Chl a provides a surrogate for primary productivity at explicit spatial locations, it does not account for the energy usage during respiration by benthic primary producers. Comparatively, estimates of whole stream metabolism can account for it, providing a better estimate of energy availability to upper trophic levels. More specifically, whole-stream metabolism quantifies carbon cycling in streams and is an empirical measure of carbon fixed and respired in the ecosystem, providing an estimate of gross primary productivity (GPP) and ecosystem respiration (ER). As such, we will measure whole stream metabolism for 4–6 weeks on each study stream during summer low flows. To accomplish this we will incorporate measurements of stream temperature with additional measures of DO, PAR, oxygen reaeration rates, and stream discharge.

Specifically, we will deploy MiniDOT dissolved oxygen (DO) and temperature loggers (Precision Measurement Engineering, Inc.) for continuous measurement (30-min intervals). We will clean DO meters weekly during deployment, as readings on optical DO meters can be impacted by periphyton growth on the surface of the sensor. We will also install photosynthetically active radiation (PAR) sensors (Odyssey PAR Light) along each stream reach to provide high resolution data (30-min interval) on the spectral range (400–700 nm) of solar radiation used by photosynthetic organisms. We will distribute the DO and PAR sensor installations along each of the stream reaches at locations most likely to be representative of reach average values. We will measure oxygen reaeration rates using a gas tracer (i.e., sulfur hexafluoride or SF₆) in all stream reaches (Wanninkhof et al., 1990).

As the stream metabolism model we will use also requires information about the volume of water in the stream, we will install a level logger and barometer (Solinst Canada Ltd.) in each stream reach/watershed (Figures 1 and 2). Stage measurements from the level loggers will be converted to volumetric discharge measurements by
developing stage-discharge relationships for each stream using the salt dilution gauging procedure (Moore, 2005). In this protocol, electrical conductivity (EC) measurements will be collected at one-second intervals using a YSI proDSS sensor Sonde (YSI Incorporated, Yellow Springs, OH). A salt slug (1 kg of salt, 6 L of water) will be prepared and dumped ~50 meters upstream of the EC sensor. We will then use the diel temperature, DO, PAR, reaeration, barometric pressure, and discharge data to calculate whole-stream metabolism using the one-station open-water exchange method (Kosinski and Merkle, 1984; Atkinson et al., 2008; Grace et al., 2015). We will determine two ecosystem metrics from these data using an inverse modeling approach based upon the diel oxygen curves (Atkinson et al., 2008; Grace et al., 2015).

Finally, riparian conditions and in-stream temperature and DO can also influence nutrient dynamics and primary productivity. Thus, we will also collect stream water samples monthly during the summer for nutrient analysis (nitrogen, phosphorus, dissolved organic carbon). We will collect three replicates of manual depth-integrated water samples at the downstream outlet of each of the study reaches. Water samples will be filtered on site using Whatman GFF filters and then placed on ice in a cooler until frozen within 6 hrs of collection. Samples will be analyzed at OSU’s Institute for Water and Watersheds (IWW) Collaboratory.

5. Describe Project Deliverables

As outcomes of the proposed research project, the deliverables will include:

- Conduct all planned research and monitoring, data collection and recording, data analysis, and data interpretation.
- Digital archives of all raw data, digitally scanned field notes, processed data, and other products produced as a result of this research to facilitate future use of the data for other projects.
- Development of a PhD thesis and associated manuscripts for publication in refereed journals.
- A technical project report of the final results for the Department of Forestry and Fire Protection.
- Presentations at meetings with stakeholders, funding agencies, and professional workshops and conferences.

6. Anticipated Project Timeline

The duration of the project will be 4 years starting June 1, 2019 and continuing until May 31, 2023 (Table 2). The timeline presented in Table 2 indicates the core activities associated with each of the main data collection components of the research.
7. Requested Funding: $694,371 (see budget and budget justification below)

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† Note: These are estimated costs that will be incurred by Green Diamond Resource Company (GDRC) over the duration of the study to facilitate its completion. These costs may include, but are not limited to, site selection, site verification, THP amendment, field crew assistance, and an approximate $30K cash contribution for equipment and supplies.

8. Principal Investigator(s) and Collaborator(s) (Include a contact person with email address, phone number, and mailing address)

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Co-PI: Catalina Segura, 280 Peavy Hall, Department of Forest Engineering, Resources, and Management, Oregon State University, Corvallis, OR, 97331, email: segurac@oregonstate.edu, Tel: 541-737-6568

Collaborators: Matt House, Drew Coe, Nicholas Simpson

Attach figures, tables, or photos as needed.
Table 1. Core zone and inner zone width requirements for WLPZ associated with Class II-S and Class II-L streams within and outside of the coastal anadromy zone (CAL FIRE, 2017).

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<th>Class II-L (feet)</th>
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<td>Watersheds outside the coastal anadromy zone</td>
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Table 2. Anticipated project timeline for main activities necessary to complete the project.

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</table>
Figure 1: Map of potential Class II stream reaches in the northern region of GDRC holdings in the Coastal Anadromy Zone in western California. The map indicates potential WLPZ treatment (green) and reference (pink) stream reaches.
Figure 2: Map of potential Class II stream reaches in the southern region of GDRC holdings in the Coastal Anadromy Zone in western California. The map indicates potential WLPZ treatment (green) and reference (pink) stream reaches.
**Figure 3:** The inset shows an example of stream temperature sensor locations (red triangles) in a stream (14, green line) adjacent to a planned cutblock (beige polygon) and in a reference stream (501, pink line), which will be paired with measurements of air temperature, photosynthetically active radiation, dissolved oxygen, primary productivity, and WLPZ structure.
References Cited


Appendix A. Budget Justification.

A. Personnel - $218,119

Bladon is requesting 1 month per year for 4 years using a base monthly salary of $9,472 for a total of $40,816. Bladon will be responsible for (1) coordination of field and laboratory research, (2) oversight of data QA/QC and analysis, (3) overall project management, (4) advisement of the graduate students, and (5) communication of the research results in reports, peer-reviewed publications, and at conferences, workshops, and meetings. A 3% annual escalation was applied.

Segura is requesting 1 month per year for 4 years using a base monthly salary of $9,496 for a total of $40,920. Segura will also be responsible for (1) coordination of field and laboratory research, (2) oversight of data QA/QC and analysis, (3) overall project management, (4) advisement of the graduate students, and (5) communication of the research results in reports, peer-reviewed publications, and at conferences, workshops, and meetings. A 3% annual escalation was applied.

Funds are requested for a graduate student (PhD) for 4 academic year terms and 4 summer terms using a base monthly salary of $4,255 for a total of $105,183. The student will be responsible for data collection, data analysis, and communication of the research results in reports, peer-reviewed publications, and at conferences, workshops, and meetings. A 2% annual escalation was applied beginning in year 1.

Additional funds are requested for an undergraduate student for 4 summers (3 months) at $15/hour for a total of $31,200 ($7,800 per summer). The undergraduate student will assist with field and laboratory data collection.

B. Fringe Benefits - $82,418

Fringe benefits for Bladon follow institutionally approved guidelines and start at 55% for a total of $23,076.

Fringe benefits for Segura follow institutionally approved guidelines and start at 55% for a total of $23,135.

Fringe benefits for graduate student follow institutionally approved guidelines and start at 29% for a total of $33,711.

Fringe benefits for the undergraduate student follow institutionally approved guidelines and start at 8% for a total of $2,496.

C. Travel - $80,452

Domestic - $80,452

Funds are requested in each of Years 1 to 4 for the PIs, graduate student, and undergraduate assistant to travel to Arcata, CA and the field sites in the region for
instrumentation of the field sites, data collection, and maintenance of field equipment. Costs for the trip are calculated as follows:

- per diem $57/day x 11 days + $134/night x 10 nights = $1967;
- vehicle $390/month x 4 months + $0.3/mi x 8400 miles = $4080;
- per trip total = $1967 x 7 trips plus monthly vehicle costs $4080 = $17849 x 4 years = $71,396

Funds are requested for 2 people to travel to AGU (San Francisco, CA) to present the research results in Year 3 and 4. Costs for the trip are calculated as follows:

- airfare $300, per diem $68/day, lodging $216/night for 5 nights for 2 people = $3,576.
- additional costs, include ground transportation $87, PI registration $480, student registration $255, abstract submissions $130;
- per trip total = $4,528 x 2 years = $9,056

D. Major equipment - none requested

E. Materials & Supplies - $141,339

Funds are requested for materials and supplies to support the project fieldwork and laboratory analysis of samples including: stream temperature loggers and housing (297 at $138 each = $40,986), photosynthetic active radiation sensors (54 at $250 each = $13,500), MiniDot dissolved oxygen sensors (20 at $1,188 each = $23,760), level loggers and barometric pressure loggers (20 at $639 and 2 at $350 respectively = $13,482), and additional field supplies to support the project (HOBO Shuttle, GPS, waders, field camera, SPOT unit, hemispherical lens, water sample bottles, filtering device = $5,771). Sub-total = 97,499 (Year 1)

Additionally, funds are requested for each of Years 1–4 for supplies used in the field and lab, which are not reusable. Specifically, funds will be used to purchase 25 mm GFF filters (178 at $17/each = $3,089), 4.7 cm glass filters (198 at $2/each = $376), SF6 gas release (832 at $3/each = $2,495), and additional miscellaneous annual supplies (ethanol, centrifuge tubes, butyl stoppers, gas sampling bags, hand crimpers, aluminum crimp seals, serum vials, equipment parts, lab safety items = $5,000).

F. Other Direct Costs - $104,511

Fees and Services - $35,640

Funds are requested in each of Years 1–4 ($8,910/year) for analytical services at the Oregon State University Cooperative Chemical Analytical Laboratory (CCAL), as follows:
Computer Services - $2,800
Funds are requested for costs ($700/yr) associated with housing and backing up of data on network servers.

Publication Costs/Page Charges - $2,000
Funds are requested in Year 3 and 4 ($1,000 each year) for publication of research results in peer-reviewed journals.

Tuition and Fees - $64,071
Graduate student tuition and fees are included in the budget for a total of 12 academic terms. Per term cost is $4,992 with an annual budgeted increase of 4.5% as projected by OSU's office of sponsored programs.

G. Total Direct Costs - $626,839

H. Indirect Charges - $67,532
The maximum permissible indirect cost rate from the funding agency (CalFire) is 12% of modified total direct costs (tuition is excluded).

I. Total - $694,371