STUDY PLAN

Title: A Paired Watershed Comparison of Hydrological and Biological Condition in Streams With and Without Cannabis Cultivation, Humboldt County, CA

Principal Investigators: E. Portugal, MS*, E. Ferguson, MS*, J. Hwan PhD, D. Manthorne, MS***, J. Kermish-Wells, MS****, K. Souza***

California Department of Fish and Wildlife
***Fisheries Branch- Cannabis and Instream Flow Unit**
****Water Branch- Cannabis Program**
830 S Street
Sacramento, Ca. 95811

*****Region 1- Habitat Conservation and Planning**
619 Second Street
Eureka, Ca. 95501

******Region 3- Watershed Enforcement Team**
7329 Silverado Trail
Napa, Ca. 94558

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I. Project Management

A. Project Description/Problem Definition

1. History or Background –

There is compelling evidence suggesting that practices associated with cannabis cultivation have the potential to cause environmental harm (Carah et al., 2015). For example, land use conversion for cannabis agriculture has been associated with habitat fragmentation and increased erosion rates leading to increased sediment yield to nearby streams (Butsic and Brenner, 2016; Wang et al., 2017); application of rodenticides around cannabis cultivation sites has been linked to the poisoning of terrestrial wildlife (Gabriel et al., 2012; Thompson et al., 2014) fertilizers and pesticides used for agriculture can degrade water quality and cause additional impacts to sensitive aquatic species (USEPA, 1994; Alvarez et al., 2008a and 2008b). Stream flow reductions from water diversions, primarily for cannabis cultivation, have the potential to degrade and seasonally eliminate aquatic habitat in some North Coast streams (Bauer et al., 2015). State and federally listed anadromous salmonids, such as Coho Salmon (*Oncorhynchus kisutch*), Chinook Salmon (*O. tshawytscha*) and steelhead (*O. mykiss*) reside in these streams and may be impacted by abnormally low-flow conditions and other potential impacts from large-scale cannabis cultivation. The quantity and magnitude of stream diversions associated with the proliferation of cannabis cultivation, as well as the cumulative impacts to fish and wildlife species has heightened the concern of the California Department of Fish and Wildlife (CDFW). However, CDFW has little empirical evidence to quantify the scale of these diversions and their potential to impact stream habitat and aquatic species.

2. Purpose –

This study seeks to determine if there are biological and hydrological impacts from water diversions for cannabis cultivation on sensitive aquatic habitat in select Humboldt County streams using a paired watershed study design. Paired watershed designs have been used in many settings to assess cumulative land use impacts at the watershed scale (Wilm et al., 1949; Wicht, 1967; McCulloch and Robinson, 1993; Loftis et al., 2001). Stream flow monitoring and biological sampling will occur in two watersheds with known cannabis cultivation, Eubanks and Mckee creeks, both tributaries to the upper Mattole River. Eubanks and Mckee creeks will both be paired to a control watershed with similar characteristics, but without known cultivation, Van Arken Creek (tributary to upper Mattole River) (Table 1).

In a focused study about streamflow variability in small headwaters Mattole River watersheds, Queener and Stubblefield (2016) found that despite geographic proximity and similar topography, geology and vegetation, a high degree of variability in dry season streamflow exists, with specific discharge sometimes spanning two orders of magnitude in the driest conditions. To better understand the specific hydrological complexities of the Mattole River watershed, four additional tributaries to the Mattole River (not part of the paired watershed comparison) will be hydrologically monitored throughout the study period to account for the 1) natural variability in base flow throughout the study region regardless of human use, and 2) legacy watershed impacts of logging and road building that occurred prior to the recent decades of cannabis cultivation. These additional hydrologic monitoring streams are Lost River, Mill Creek, Blue Slide Creek and Canoe Creek (Table 2).

3. How will data and information from the project be used? –
The results from this study will provide quantitative hydrological and biological data that could support efforts to establish sustainable levels of cannabis cultivation in sensitive watersheds on the North Coast and inform similar studies throughout the State, where applicable. If surface water diversions for cannabis cultivation are found to result in significant or adverse impacts to sensitive fish species, the results of this study may inform regionally specific flow thresholds, gage installations, local authorizations, regional forbearance periods, outreach efforts, or future voluntary/cooperative agreements.

4. What are the biological implications of the project? –
Biologically relevant aquatic habitat quality parameters (i.e., water temperature, dissolved oxygen [DO] concentration, benthic macroinvertebrate [BMI] community composition and fish passage at different life history stages (Habitat Retention Method [HRM]) will be analyzed in relation to stream flow in watersheds with and without current cannabis cultivation.

B. Project Organization and Responsibilities

1. Elijah Portugal, David Manthorne, Jason Hwan and Lillian McDougall
   a. Site Selection
2. Elijah Portugal
   a. Mapping of current cultivation in study watersheds via remote sensing methods following the methodology of Bauer et al. (2015) and Butsic and Brenner (2016).
3. Elijah Portugal, Kelly Souza, David Manthorne and staff from Sanctuary Forest (a nonprofit land and water trust located in the Mattole River headwaters) and Humboldt Redwoods State Park
   a. Land Owner Access
4. Jason Hwan, Elijah Portugal, David Manthorne
   a. Instream Flow
      1. Pressure Transducer Deployment
      2. Dissolved Oxygen Logger Deployment
      3. Discharge Measurements
      4. Site Selection
   b. Habitat Retention Method
      1. Site Selection
      2. Survey Measurements
   c. Data Analysis and Reporting
      1. Quality Assurance and Quality Control

5. Kelly Souza, Erin Ferguson, Elijah Portugal, Jason Hwan

a. Bioassessment

1. Benthic Macroinvertebrate (BMI) Collection
2. Water Quality Parameters

a. Dissolved Oxygen (DO)

b. Water Temperature

b. Data Analysis and Reporting

1. Quality Assurance and Quality Control (QA/QC)

C. Study Design

6. Research questions

a. Assuming all other watershed parameters are similar (e.g., drainage area, mean annual precipitation, bedrock geology, etc.), is stream flow significantly different between watersheds with substantial levels of cannabis cultivation ('substantial levels' will be determined through manual mapping efforts based on the total plant count/study watershed) and watersheds without known cultivation during the outdoor growing period of May - October?

b. What is the predicted amount of water consumption for cannabis production (quantified per canopy area from manual mapping efforts) and other human water use in the three paired watersheds?

c. If stream flow is impaired due to diversions to support substantial levels of cannabis cultivation, how does this impact fish passage as determined through the HRM?

d. How does the overall measure of stream health compare between streams with varying levels of cannabis cultivation, as well as to reference streams?

e. Are BMI community structure and composition significantly different between streams with and without substantial levels of cannabis cultivation?

f. Are temperature and dissolved oxygen significantly different between streams with and without substantial levels of cannabis cultivation. If so, how do these compare throughout the season?

g. How does temperature, dissolved oxygen and BMI composition compare to published thresholds relevant to aquatic habitat quality?

7. What statistical test(s) or methods will be used to answer the questions?

a. In all study watersheds (3 paired watersheds and 4 additional watersheds), pressure transducers (PTs) will be deployed in early May to collect continuous water stage data every 15 minutes. A minimum of 4 and up to 6 discharge measurements will be collected throughout the low flow period (May-Oct). These data will be used to develop stage-discharge rating curves to provide estimates of stream flow, which will be compared amongst the study watersheds. Discharge data will be collected in accordance with the CDFW Instream Flow Program Standard Operating Procedure for Discharge Measurements in Wadeable Streams in California (CDFW, 2013). When late season flows drop below the minimum level possible for collection via electromagnetic velocity meters (e.g., Hach meters) volumetric measurements will be collected following examples from peer-reviewed literature (Queener and Stubblefield, 2016). A literature review will be undertaken to identify other existing peer- reviewed literature (e.g., Queener and Stubblefield, 2016) and other flow data from previous years that meet CDFW QA/QC requirements within the study area. These data will be considered and where possible included in the analysis.

b. Manual mapping from current aerial imagery of cannabis cultivation sites will be completed within study watersheds with cannabis cultivation following the methods of Bauer et al. (2015) and Butsic and Brenner (2016). A literature review will be conducted to estimate the amount of human water use for non-cannabis needs within populated study watersheds with cannabis cultivation. Manual mapping of cannabis sites will result in an estimated total plant count and amount of cannabis canopy area per watershed. This will then be converted to a predicted amount (volume and/or rate) of water consumption by cannabis at the watershed scale. The daily average consumption of water either at the scale of canopy area (greenhouse and outdoor) or per individual cannabis plant throughout the growing season will be based on best available data (e.g. literature review and consultation with regional and State Water Board staff engaged in similar efforts).The predicted rate of water consumption by cannabis at the watershed scale will be compared to the flow rate measured with PT gages in watersheds with substantial levels of cannabis cultivation.

c. To determine if there are statistically significant differences in stream flow between watersheds with and without cannabis cultivation, slope and intercept terms of linear models will be compared. The response variable in the models will be stream flow and independent variables will include site ID and day of water year. Model selection, based on an information- theoretic approach (Burnham and Anderson, 2002) using the Akaike Information Criterion (AIC) corrected for small samples sizes (AICc), will be used to rank three candidate models with different independent variables. Specifically, these will include 1) day of water year, 2) site ID + day of water year, and 3) a site ID x day of water year interaction. AIC uses the log-likelihood function to rank candidate models and applies a penalty for more complex models (Akaike, 1973). The top-ranking model will have the lowest AICc value and if models are within 2 AICc of the top- ranking model, they are considered to have strong support. For our analyses, model-averaging (based on AICc weight) will be used for all models with ΔAICc < 2.

d. The HRM (Nehring, 1979; CDFW, 2016) determines flow thresholds for different life stages of salmonids. Data collected from pressure transducers will be used to create stage-discharge rating curves to provide stream flow estimates relative to modeled thresholds derived from HRM. Where possible, discharge from the ungaged watersheds will be compared to existing gages in the area to establish the water year type during the study period and to calculate exceedance flows.

e. Benthic macroinvertebrates (BMIs) will be sampled using a reach-wide benthos approach to assess overall stream health (Ode et al., 2016). One composite benthic macroinvertebrate sample will be collected in one 150-m reach for each stream at least three times over the summer/early fall low flow season (May-October). An index of biological integrity, ratio of observed over expected index (O/E index) and California Stream Condition Index (CSCI) will be calculated for each composite sample. All benthic macroinvertebrate samples will be processed by taxonomists standardized by the Southwest Association of Freshwater Invertebrate Taxonomists.

f. In addition to BMI samples collected using the SWAMP protocol, an enhanced sampling event will occur once during the low flow season (mid-July) in Van Arken and Eubanks creeks. In each of these streams, enhanced sampling will include seven composite BMI samples collected from seven additional reaches. Reaches will be delineated and sampled in accordance with the SWAMP protocol; however, only a subset of the physical habitat parameters will be collected. BMIs collected from each reach will comprise a unique sample to allow for statistical comparisons. The enhanced sampling will allow for a more robust comparison of taxonomic diversity among streams.

g. Using abundance data of all taxonomic groups collected, non-metric multidimensional scaling (NMDS) and permutational multivariate analysis of variance (PERMANOVA) will be used to compare macroinvertebrate communities within the two paired watersheds (one with and one without known cultivation). NMDS is an ordination technique that scales multidimensional data (in this study, the abundance of each taxonomic group represents a dimension) to a lower number of dimensions to aid with the visualization and interpretation of results (Kenkel and Orloci, 1986). Similar to other ordination methods, NMDS produces an ordination based on a distance or dissimilarity matrix, with similar groups closer to each other (or overlapping) and dissimilar groups farther from each other in ordination space. PERMANOVA allows for testing statistical differences among groups using distance matrices.

h. Temperature and DO concentrations will be compared between watersheds with and without cannabis cultivation. Further, using model selection, candidate models will be compared to determine which variables influence DO concentrations (response variable). Independent variables will include various combinations of stream flow, site ID, canopy cover, temperature, and geomorphic channel type.

i. Temperature and DO concentrations from continuous data loggers will be referenced to the North Coast Regional Water Quality Control Board (NCRWQCB) standards established in the North Coast Basin Plan (RWQCB, 2009) and standard biological thresholds for salmonids will be determined through a survey of peer-reviewed literature.

II. Will study provide legally defensible data?

Yes, all sampling methods and Standard Operating Procedures (SOPs) will follow peer-reviewed standards.

III. Project Resource Needs

A. Budget

Total operating expenses include equipment + lab processing + travel and is estimated at $70,000. Equipment expenses include the initial capital outlay for sampling equipment for this study with equipment that will be used again for future studies. Labor and benefits (55.57%) for three Senior Environmental Scientists and a Senior Environmental Scientist Supervisor is estimated at $290,114 for a total cost of $360,814.

B. Field activities

1. Obtain landowner access agreements for all sites in study watersheds, as well as a permit from California State Parks before conducting work within Humboldt Redwoods State Park.

2. To the extent possible, we will ground-truth control sites and consult with scientific staff from Humboldt Redwoods State Park to verify the absence of current cannabis cultivation.

3. Develop flow criteria using the HRM at three riffle transects per watershed. This will include an auto level survey of the streambed and water surface elevations, with a representative discharge measurement (only one discharge site is required if there are no tributary inputs or diversions among transects).

4. At least one pressure transducer (most likely two per stream) will be deployed in a pool with stable bedform and a barometric logger will be installed out of water to adjust for atmospheric pressure. A minimum of four and up to six discharge measurements will be taken over a range of flows to produce a stage-discharge rating curve. Waddle (2001) recommends a minimum of three discharge measurements to develop a relationship between stage and discharge, but additional measurements can improve the accuracy of the relationship.

5. All reach-wide benthic macroinvertebrate collections will be completed following the Surface Water Ambient Monitoring Program (SWAMP) bioassessment protocol (Ode et al., 2016). In each stream, BMI will be collected from one 21-transect reach ranging in length from 150-250 meters (depending on stream width and site access constraints). The transect samples will be combined into one composite sample. Physical habitat measurements will also be taken at each reach. Each stream will be sampled for BMI at least three times during the summer low flow period (May-October) in order to determine if BMI community composition changes throughout the low flow period (May-October) and if it differs between streams with and without cannabis cultivation. If surface flow persists through the summer low

flow period, a fourth BMI sample may be collected.

6. Enhanced sampling will take place in two of the study streams once during the low flow season. In Van Arken and Eubanks creeks, seven additional reaches will be sampled following a modified SWAMP protocol for BMI collection. Each reach will comprise an individual sample for a total of seven enhanced samples per stream. Additional physical habitat measurements will be taken at each of the sampled reaches. Physical habitat measurements will include pebble counts, embeddedness and presence/absence of micro- and macroalgae.

7. Three dissolved oxygen/temperature sensors will be deployed in three separate pools (located near the pressure transducers) with consideration given to ensuring unrestricted flow, minimization of temperature changes unrelated to water temperature (canopy cover), and similar geomorphic reach type (i.e. bedrock or alluvial setting). Site selection and installation will be guided by manufacturer (Onset Computer Corp., Bourne, MA) specifications and the National Field Manual for the Collection of Water- Quality Data (Rounds et al., 2013).

IV. Coordination needs

a. Land owner access - Elijah Portugal, David Manthorne, Kelly Souza, and staff from Sanctuary Forest and Humboldt Redwoods State Park
b. Calibration/deployment/recovery of pressure transducers and dissolved oxygen loggers - Water Branch, Fisheries Branch and Region 1 staff
c. Targeted discharge measurements - Water Branch, Fisheries Branch and Region 1 staff
d. Benthic macroinvertebrate sampling and processing - Fisheries Branch staff and CDFW Aquatic Bioassessment Lab
e. Data Analysis and Reporting - Fisheries Branch, Water Branch, and Region 1 staff

V. ESA Considerations

1. This study will not result in the take of any State or federally listed species.

VI. Data Acquisition and Management

A. Sample Site Selection:

1. An initial list of 37 potential study watersheds located throughout Region 1 were selected based on aerial imagery, ground reconnaissance, and professional judgement of CDFW scientific and law enforcement staff in the region. Priority was given to watersheds where high value fish and wildlife habitats overlap with substantial levels of current and historic cannabis cultivation. Within the list, study watersheds and sites within the watersheds

were selected based on willing landowner access and physical, hydrological, biological and geological similarities (Table 1). Other considerations included accessibility, staff safety, and field staff capacity.

2. **Statistical and scientific rationale for choosing sites**
Study watersheds were selected based on close similarities in the watershed parameters listed in Table 1. Drainage Area, Mean Annual Precipitation (MAP), 2-year Peak Flood Estimates, Bedrock Geology and Longest Length of Flow Path were preferentially weighted over other watershed parameters as indicative of suitable hydrological similarities for comparison. Pairing of watersheds only occurred if drainage areas and MAP between watersheds were calculated within 15% of each other. Additionally, all sites were located within CDFW's California Coastal Salmonid Population Monitoring sample frame (CDFW, 2011).

B. Sampling Procedure (Standard Operating Procedures, SOPs)

1. Pressure transducers (including barometric loggers) and stilling wells will be deployed by field staff trained by a CDFW Hydraulic Engineer following the SOP developed by Utah Department of Environmental Quality (Utah SOP; DWQ, 2014). Stage data will be collected continuously at 15 minute intervals with data downloaded at least five times during the study period.
2. Discharge measurements will be collected at a minimum of four times over the study period at each stream following CDFWs SOP for discharge measurements in wadeable streams (CDFW, 2013) and standard volumetric low flow gaging techniques derived from literature.
3. Dissolved oxygen sensors will be deployed following the United States Geological Survey (USGS) SOPs (Wagner et al., 2006; Rounds et al., 2013) and data will be recorded on a continuous basis at 15 minute intervals. Post deployment, all DO sensors will be inspected in the field following manufacturer's specifications with data downloaded at least three times during the study period.
4. HRM will be conducted at three riffles per stream, 1-2 times over the study period following Water Branches HRM SOP (CDFW, 2016).
5. Reach-wide benthic BMI samples will be collected three times during the summer low flow period (May - September) in the three paired watersheds following the CA Water Board's SWAMP protocol (Ode et al., 2016). Additional reach-wide benthic BMI samples (enhanced BMI sampling) will be collected in two study streams following a modified SWAMP protocol. Collection will occur once during the low flow period.

C. Calibration Procedures and Frequency

1. Instrument calibration of pressure transducers, barometric loggers, flow meters, and dissolved oxygen loggers will be undertaken following manufacturers specifications prior to deployment and use.
    a. Pressure Transducers
    b. Barometric Loggers
    c. Dissolved Oxygen Loggers

- **d.** Flow Meters
2. Frequency and timing of calibration:
   - a. Factory calibrations will be used before initial deployment. Recalibrations will be performed following manufacturers specifications.
3. Documentation of calibration checks
   - **a.** Performance of calibration checks will be recorded on data sheets.
4. Inspection and maintenance of instruments, equipment, and supplies
   - **a.** This will be conducted as needed and consistent with the manufacturers' specifications and guided by the USGS's National Field Manual for the Collection of Water-Quality Data (Wagner et al., 2006; Rounds et al., 2013).

D. Data Quality Assurance/Quality Control

1. Discharge data will be QA/QC'ed by CDFW staff following Standard Operating Procedures.
2. Continuous sensor data (PT, Temperature and DO) will be offloaded from sensors periodically throughout the study period ensuring data quality.
3. BMI data will be QA/QC'ed following the CA Water Board's SWAMP protocol (Ode et al., 2016).
4. HRM data will be QA/QC'ed following Water Branch SOPs.

VII. Climate Change

The specific effects of climate change in our study area are impossible to predict with certainty but salmonid life history is very responsive to local environmental conditions that are directly linked to climate (Crozier et al. 2008). It is likely that existing drought conditions will increase in frequency and duration and that winter peak flow events will increase in magnitude, all of which will likely result in less surface flow available for aquatic biota in the late summer months. Aquatic biota in the naturally intermittent streams in the upper Mattole watershed are particularly sensitive to drought. An increase in the duration of dry habitat conditions and a loss of hydrologic connectivity is likely to negatively impact survival of already impacted salmonids and other instream species (Jaeger et al. 2014). Increased magnitude and frequency of high water temperatures throughout the northwest U.S. associated with climate change are also likely to negatively influence salmonid growth, survival and fitness (Isaak et al. 2012). Asarian and Walker (2016) found that on average in northern California and southern Oregon from 1952-2012 that there are declining trends in late September precipitation and summer streamflow. This trend is likely to continue under climate change and will decrease the quality of instream habitat in the study area. The negative influence of climate change on surface flow, combined with water withdrawals for cannabis cultivation and domestic use in headwaters of Mattole tributaries, will not result in favorable conditions for the persistence or recovery of threatened salmonids.

Table 1: Watershed parameters used to identify suitability for paired watersheds. The control watershed without known cannabis cultivation is highlighted in green* with paired watersheds with known cannabis cultivation to the right.

Watershed Parameter	Van Arken* (Upper Mattole)	Upper Eubanks Creek (Upper Mattole)	Mckee Creek (Upper Mattole)
Drainage Area[1] (sq mi)	2	2.3	2.1
Salmonids spp present[2]	Coho Salmon, Chinook Salmon, Steelhead	Coho Salmon, Chinook Salmon, Steelhead	Coho Salmon, Chinook Salmon, Steelhead
Mean annual precip, basin-wide (in)[1]	68.9	69.7	69.1
Relief (ft) (max - min elev)[1]	772	886	884
Max basin elevation[1] (ft)	1723	1751	1814
Min basin elevation[1] (ft)	952	865	930
Mean basin elevation[1] (ft)	1283	1253	1298
Watershed aspect[3]	East side	East side	East side
Mean basin slope[1] (%)	37.4	36.5	37.0
Percent DA composed of forest[1] (%)	65.5	61.6	59.1
Avg percent of impervious area[1] (%)	0	0	0.1
Percent of developed (urban) land[1] (%)	1.0	2.1	4.2
Longest length of flow path[1] (mi)	2	3	3

Watershed Parameter	Van Arken* (Upper Mattole)	Upper Eubanks Creek (Upper Mattole)	Mckee Creek (Upper Mattole)
Bedrock Geology[4]	100% Franciscan Complex	100% Franciscan Complex	100% Franciscan Complex
2-yr Peak flood[1] (cfs)	218	251	229
Known Cannabis Cultivation	No	Yes	Yes

[1]Watershed Parameters derived using USGS StreamStats (2016a) The StreamStats Program for California. Available: http://water.usgs.gov/osw/streamstats/california.html ,Accessed: March 26, 2018.

[1]2 Yr Peak Flow is derived from StreamStats following Gotvald et al. (2012).

[2]Salmonid spp present is based on CDFW's Biogeographic Information and Observation System (BIOS) data and whether the stream was included in the CDFW's Coastal Monitoring Program Generalized Random Tessellation sample frame.

[3]Watershed Aspect is watershed scale orientation of the study watershed relative to the larger watershed valley (i.e., study watershed located on the east or west side of the larger watershed valley).

[4]Bedrock Geology is from USGS Geologic Units of CA accessed via google Earth April 4, 2018. Yager Terrane = sandstone, shale and conglomerate; Franciscan Complex = sandstone, mudstone and conglomerate.

Table 2: Watersheds included in study for hydrologic analysis and HRM but not included in the paired watershed comparison.

Watershed Parameter	Mill Creek (Upper Mattole)	Lost River Creek (Upper Mattole)	Upper Blue Slide Creek (Upper Mattole)	Canoe Creek (SF Eel Trib)
Drainage Area[1] (sq mi)	2.3	1.4	7.9	10.3
Salmonids spp present[2]	Coho Salmon, Chinook Salmon, Steelhead	Coho Salmon, Chinook Salmon, Steelhead	Coho Salmon, Chinook Salmon, Steelhead	Coho Salmon, Chinook Salmon, Steelhead
Mean annual precip, basin-wide (in)[1]	73.6	71.0	63	61.6
Relief (ft) (max - min elev)[1]	1166	742	1720	3179
Max basin elevation[1] (ft)	2169	1813	2411	3364
Min basin elevation[1] (ft)	1003	1070	691	185
Mean basin elevation[1] (ft)	1456	1348	1330	1666
Watershed aspect[3]	West side	East side	East side	West side
Mean basin slope[1] (%)	42.3	32.4	32.2	38.9
Percent DA composed of forest[1] (%)	59.4	65.6	55.1	77
Avg percent of impervious area[1] (%)	0.1	0.1	0.1	0

Watershed Parameter	Mill Creek (Upper Mattole)	Lost River Creek (Upper Mattole)	Upper Blue Slide Creek (Upper Mattole)	Canoe Creek (SF Eel Trib)
Percent of developed (urban) land[1] (%)	1.8	4.3	2.5	0.3
Longest length of flow path[1] (mi)	3	2	6	5
Bedrock Geology[4]	100% Franciscan Complex	100% Franciscan Complex	61% Yager Terrane, 27% Franciscan Complex, 11% ultramafic, <1% Pliocene marine	100% Yager Terrane
2-yr Peak flood[1] (cfs)	264	163	692	861
Known Cannabis Cultivation	Yes	No	Yes	No

[1]Watershed Parameters derived using USGS StreamStats (2016a) The StreamStats Program for California. Available: http://water.usgs.gov/osw/streamstats/california.html ,Accessed: March 26, 2018.

[1]2 Yr Peak Flow is derived from StreamStats following Gotvald et al. (2012).

[2]Salmonid spp present is based on CDFW's Biogeographic Information and Observation System (BIOS) data and whether the stream was included in the CDFW's Coastal Monitoring Program Generalized Random Tessellation sample frame.

[3]Watershed Aspect is watershed scale orientation of the study watershed relative to the larger watershed valley (i.e., study watershed located on the east or west side of the larger watershed valley).

[4]Bedrock Geology is from USGS Geologic Units of CA accessed via google Earth April 4, 2018. Yager Terrane = sandstone, shale and conglomerate; Franciscan Complex = sandstone, mudstone and conglomerate.

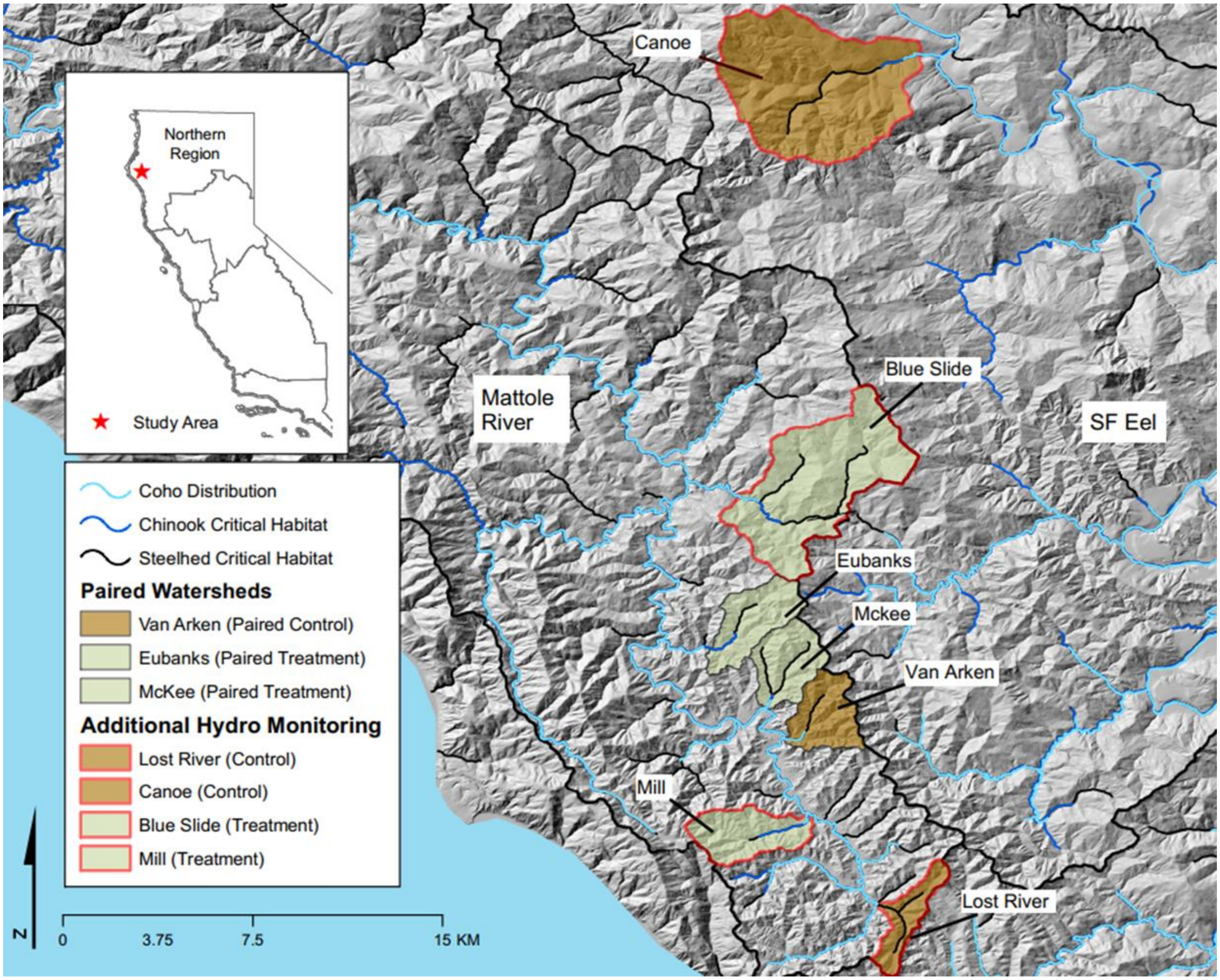

Figure 1: The three paired watersheds are shown in the center of the figure. Green fill indicates watersheds with known cannabis cultivation and control watersheds are shown with brown fill. Watersheds highlighted in red will have hydrologic monitoring and HRM conducted as opposed to the full suite of study methods described above.

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