KINGS RIVER EXPERIMENTAL WATERSHED

RESEARCH STUDY PLAN

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This is still a draft document . Parts of this document have been completed based on reviewers comments; parts are still being developed as new components are added to the study.

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Research Study Plan for
Kings River Experimental Watershed

0. Executive Summary

The intention of the Kings River Experimental Watershed (KREW) is to be as holistic and integrated as possible with a focus on headwater stream ecosystems and their associated watersheds. It is designed as a long-term study with a 15-year minimum period of study starting in 2000. KREW is part of the larger Kings River Project which is working to develop forest management techniques for sustainable forest ecosystems in the Sierra Nevada. The approach includes the following activities.

- Prescribed fire and uneven-aged, small-group tree harvesting
- Maintain older trees, large snags, and large woody debris throughout the landscape
- Maintain a mosaic of vegetation types and ages that mimic, to the extent possible, the historical distribution of vegetation resulting from frequent, low-intensity fires prevalent before European settlement of the western United States

KREW has the following goals.

- Quantify the existing condition and variability in the characteristics of headwater stream ecosystems and their associated watersheds
- Evaluate the effects of forest management on the characteristics of stream ecosystems and their associated watersheds
- Shares the approach for the Kings River Project of which it is a part

The development plan for KREW is outlined below.

- 4 years to instrument and design (2000-2003)
- 4 years of pretreatment data:
  - -Providence Site started 1 October 2002
  - -Bull Site started 1 October 2003
- 2 years to treat both areas:
  - -Providence Site starts fall of 2006
  - -Bull Site starts fall of 2007
- 5 to 7 years of post-treatment data collection

KREW is being designed to evaluate pattern and process on the landscape. The selected measurements will allow evaluation of:

- Nutrient budgets (water, soil, and vegetation)
- Sediment budget

- Soil condition
- Stream food web and/or energy budget
- Geologic and geomorphic processes
- Vegetation and fuel loading characteristics
- Riparian microclimate
- Air pollution loadings

KREW will be addressing several questions posed in the Sierra Nevada Framework (US Department of Agriculture, Forest Service 2001).

1. What is the effect of fire and fuel reduction treatments (i.e., thinning of trees) on the riparian and stream physical, chemical, and biological conditions?
2. Does the use of prescribed fire increase or decrease the rate of erosion (long term versus short term) and affect soil health and productivity?
3. How adequate and effective are current stream buffers at protecting aquatic ecosystems?

Additional research questions and hypotheses can be found in the specific sections of this study plan.

Measurements of physical, chemical, and biological variables are necessary to accomplish a holistic watershed study. The following variables and approaches were started at the Providence Site in 2002 and the Bull Site in 2003 with the exception of fuel loadings and channel characteristics which will be done in 2005.

Table: 0.0-1—*KREW physical, chemical and biological measurements summary.*

Document section	Measurement category	Measurement	Frequency	Spatial unit
5.1	Stream Discharge	Measurement by ISCO 730 Bubbler®, Aquarod®, and Telog	15 minutes	1 point / watershed
5.2	Meteorology	Temperature, Relative humidity	15 min. average, 24 hr. maximum, 24 hr. minimum	2 points / watershed site
		Solar radiation	15 min. average flux, 24 hr. totalized flux density	2 points / watershed site
		Wind speed, Wind direction	15 min. sample, daily max. 10 sec. gust speed and direction	2 points / watershed site
		Wind run	24 hr. total	2 points / watershed site
		Snow depth	15 min. sample	2 points / watershed site
		Precipitation / Snow water equivalence	1 min. average every 15 minutes, daily change in total	1 point / watershed site
5.3.1	Stream Channel Characteristics and Geomorphology: Baseline Data	Surveyed longitudinal profile data: thalweg, water surface, bankfull indicators	One-time measurements that may be repeated after treatments.	Entire length of each stream
		Transect data: pebble counts to determine D50 particle size, bankfull width, bankfull maximum depth, flood prone area width, bankfull mean depth		10-30 temporary transects / stream
5.3.2	Stream Channel Characteristics and Geomorphology: Permanent Study Reaches and Cross-sections	Stream Condition Inventory:	Twice before treatment and for at least the first three years after treatment.	
		Sensitive reach measurements: temperature, bankfull, LWD count, pebble count, 3 monumented cross sections, gradient (at each cross-section), also width / depth ratio and entrenchment at each monumented cross-section plus an additional 5 locations		Entire length of each stream
		Survey segment: habitat type ,pool count, maximum pool depth, percent fines in the pool tail, whether or not wood formed the pool, 50 transects to evaluate: bank stability, shade, bank angle, aquatic fauna		Lowest 1000m of each stream, unless the stream is shorter than 1000m than the entire stream length is used

Document section	Measurement category	Measurement	Frequency	Spatial unit
5.3.2	Continued… Stream Channel Characteristics and Geomorphology: Permanent Study Reaches and Cross-sections	Herbst Physical Habitat Survey Reach Data: habitat type (pool / non-pool), stream temperature, pH, conductivity, turbidity, flume size and stage, slope at 4 points in reach spaced at 25m, photos upstream and downstream at each slope point Transect Data: wetted width, bank cover (both banks), bank angle (both banks), vegetative shading (both banks and upstream and downstream), stream depth and velocity (5 points per transect), cobble embeddedness (25 cobbles total)	Annual and concurrent with invertebrate sampling.	One 100 m reach / stream 10 transects / reach
5.4	Erosion and Sedimentation	Sediment load – wet volume Also, a sub-sample is analyzed and results are extrapolated to estimate the total dry volume and mass, percent organic versus inorganic, and size class distribution of inorganic fraction	Annual	1 sediment basin / watershed (exceptions being B203 and B204 which have no basin)
5.5	Turbidity and Suspended Sediment	Measurement by Forest Technology Systems DTS-12 Suspended sediment sampling via grab and ISCO 6712 automated sampler	15 minutes Storm based	1 point / watershed 1 point / watershed
5.6	Soil Characteristics	Field measurements (see Section 5.5)	Once before and once after treatment	Subset of points in 150m grid that has been densified in B201 and P304 watersheds
5.7.1	Shallow Soil Water Chemistry	Prenart Vacuum Lysimeter Each Prenart system captures soil water at six locations with samples taken from two depths at each location: 13 cm and 26 cm, for a total of 12 samples. Resin Lysimeters buried at 13cm depth	Integrated samples are retrieved and sent for analysis every 2 weeks during wet season. Annual	Providence Site has one Prenart system / watershed. The Bull Site has no Prenart systems. 2 / soil grid point and one at each Prenart sampling location.

Document section	Measurement category	Measurement	Frequency	Spatial unit
5.7.2	Snowmelt and Rainfall Chemistry	Resin throughfall lysimeters placed on ground surface Snow-melt collectors, co-located at each Prenart site. Six collectors sample throughfall precipitation and one is in an open canopy location, for a total of 7 collectors per Prenart system.	Annual Integrated samples are retrieved and sent for analysis every 2 weeks during wet season.	1 / soil grid point. 1 above each Prenart sampling location 7 collectors / Prenart system
5.7.3 5.7.4	Stream Water Chemistry	ISCO 6712 samplers Grab samples	Collection and retrieval schedule is based on discharge, season and current weather forecast. Difficult to summarize, please see section 5.6.3.	1 point / watershed
5.8	Riparian Vegetation	20 m Transect perpendicular to stream Herbs – % cover by species using 4 1X1 m quadrats located along transect line with 2 at stream bank. Shrubs – % cover by species using the line-intercept method at every 1m along the line. Trees - % cover, density and recruitment by species using a 10X20 m belt transect along the 20 m transect.	Annual	1 transect every 200 m, 5-10 transect per watershed
5.8	Upland Vegetation	20 m Transect at random azimuth Herbs – % cover by species using 4 1X1 m quadrats located along transect line with 2 at stream bank. Shrubs – % cover by species using the line-intercept method at every 1m along the line. Trees - % cover, density and recruitment by species using a 10X20 m belt transect along the 20m transect.	Annual	Watershed divided into equal-sized partitions, with 2 transects per partition, resulting in 6-12 transects per watershed. The beginning of the transect will be placed on existing soil grid points.
5.8 not included in document	Riparian Vegetation and Microclimate	CSUF graduate student thesis of Dana Nagy, major professor Dr. Ruth Ann Kern	2-year study	Only done at Providence Site

Document section	Measurement category	Measurement	Frequency	Spatial unit
5.10	Stream Invertebrates	30-cm wide D-frame net, 250-micron mesh Taxa identified to genus (a few only to Phylum, order, Family)	Annual	100 m reach / stream where 3 riffles and 3 pools are randomly sampled
5.11	Algae / Periphyton	USGS performed pilot study in 2002—awaiting results Community structure Rock scrapings Biomass (measured as chlorophyll-a, pheophytin-a, and ash-free-dry mass)	Annual *(not sure about long term inclusion)*	100 m reach / stream used for sampling, co-located at a riffle with the invertebrate reach.
Not included in document	Fish	CSUF graduate student thesis of Nicholas Basile, major professor Dr. Steven Blumenshine	Annual *(not sure about long term inclusion)*	Only found at Bull Site

1. Project Identification

Title: Kings River Experimental Watershed

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Identification Number: ?

Identification of Related Study Plans: Kings River Sustainable Forest Ecosystem Project, Sierra National Forest, California

Associated Question Group: ?

Persons that have served as reviewers of this study plan are listed in Appendix 18.9

2. Problem Reference and Literature

Characteristics of streams and rivers serve as integrators of broader environmental conditions because they reflect the conditions of the surrounding landscape (Hunsaker and Levine, 1995; Naiman and Bilby, 1998). Activities within a watershed, whether natural or anthropogenic (human induced), influence the most basic aspects of the hydrological cycle. Vegetation absorbs and transpires water to the atmosphere; roads channelize water to streams; wildfire and heavy equipment can decrease soil permeability causing an increase in erosional sheetflow; and impoundments alter the timing, frequency, and intensity of peak flows. All of these alterations, singly and in combination, directly impact the habitat distributions; the trophic structure; and the physical, chemical, and biological processes (such as sediment transport, nitrogen cycling, and primary production), and the demography of the biological communities.

Stream and river habitats (and their associated biotic communities) are significantly more affected by human activities than many upland habitats occupied by charismatic megafauna (Naiman and Bilby, 1998), but forested stream ecosystems have received relatively little attention and resources from the Forest Service in the Sierra Nevada, as compared to terrestrial wildlife. Clearly, pressures from human population growth and resource consumption will not allow streams and rivers to return to their natural state; land use change will continue. Consequently, developing predictive knowledge of how land use alterations affect aquatic resources is a major challenge for the foreseeable future. A basic ecological understanding of the structure and dynamics of running waters is essential for formulating sound management and policy decisions (Naiman and Bilby, 1998).

2.1 Stream Discharge

The most fundamental of hydrologic measurements that characterizes all river and stream ecosystems is discharge (Gore, 1996). Discharge is a result of incoming precipitation as altered by infiltration, storage, evapotranspiration, and other processes (Leopold, 1994). In the short term, discharge directly controls the channel morphology and significantly impacts riparian vegetation and the organisms that inhabit the stream and riparian corridor.

Removing entire forest stands through clear cutting and stand-replacing fires definitely alters discharge. Water infiltration rates are often diminished following fire owing to the plugging of surface pores and increased fire-induced water repellency. The contribution of hydrophobicity to overall postfire erosion of forest soils remains largely unknown. The current state of science does not allow us to assign various levels of importance to the factors that generate postfire soil erosion (Fisher and Binkely, 2000). Current Forest Service management actions such as thinning and prescribed burning may alter stream discharge enough to potentially change channel morphology, aquatic species assemblages, and riparian vegetation.

Stream discharge measurements have traditionally been the domain of civil engineers focused on measuring discharge during the wettest periods of the year because that is when water can be redirected

for human use (Mosley and McKershar, 1993). When ecologists examine streams it becomes evident that low flows are as important, or more important, than peak flows to the flora and fauna of a stream corridor. This is especially true when working in first order headwater streams.

KREW staff consulted a variety of hydrologists and technical publications when determining how to measure discharge. The three publications used most frequently were: Water Measurement Manual, USDI, 1967; Isco Open Channel Flow Measurement Handbook, Grant and Dawson, 1997. Rand Eads and Jack Lewis, Pacific Southwest Research Station, USDA Forest Service, Arcata, CA also provided invaluable ideas and expertise. A detailed discussion of the KREW staff's decision of how to measure discharge exists in methods (see section 5.1).

2.2 Meteorology

Measuring the seasonal variation in air temperature, solar radiation, and precipitation is considered basic to all hydrologic and natural resource studies (Hanson, 2001; Hanson et al., 2001). The suite of meteorological variables recommended to adequately measure climate, precipitation, and snowpack includes the following meteorological variables: wind direction, wind speed, wind run, relative humidity, temperature, solar radiation, precipitation, snow depth, and snow water equivalence (SWE) (Marks, 2001). Similar measurement efforts are documented at the Reynolds Creek Experimental Watershed (Hanson, 2001; Hanson et al., 2001; Marks et al., 2001; Slaughter et al., 2001).

Pre-existing permanent and portable meteorology stations exist near the KREW sites and accurately collect summertime data when the threat of fire is a concern; however, these stations were not designed for wintertime use. These stations have tipping bucket gages that are incapable of measuring frozen precipitation (Salzay, 2001) and the instruments towers are not tall enough to prevent sensor burial under the typically deep Sierra Nevadan snow pack. Since the most significant precipitation events occur in the winter or spring, the pre-existing stations are considered inadequate for the KREW study. Considering the 10-20 year lifespan of KREW, permanent installations that are capable of functioning in all types of wintertime conditions are required.

2.3 Stream Channel Characteristics and Geomorphology

Universal physical laws govern streams, yet every stream exists in a unique way within its watershed. Differences in watershed size, climate, location, geology, and past management activities are only a few of the factors that create the range of fluvial forms we see. Each stream must balance erosion, transport and deposition in the context of these factors. To understand the effects of a given management practice it is first necessary to establish a baseline of existing physical conditions for the stream channel. With this foundation of technically correct and comparable data, it is possible to track changes in the character of the stream (Harrelson et al., 1994).

The importance of quantitative over qualitative measurements to characterize and/or classify channel characteristics is widely accepted in the following literature. Leopold et al. (1964) claim that

stream channels can be classified in terms of eight major variables: width, depth, velocity, discharge, slope, and roughness of the bed and bank materials, sediment load, and sediment size. Each of these variables can be measured in a quantitative manner. Harrelson et al. (1994) state that the ability to accurately make and replicate stream channel measurements over a period of years is vital and provides a foundation of technically correct and comparable data, which can then be used to track changes in the character of the stream. The Stream Condition Inventory (USDA, 1998) concentrated on attributes that had been demonstrated through research to be indicative of stream condition, could be sampled by seasonal field crews, and had low enough measurement error to be useful in describing differences with a moderate to high level of confidence. Herbst (2001) found that measurements of physical form do provide useful information on the environmental setting of streams but fail to evaluate the biological health or integrity of stream ecosystems. Herbst developed protocols that combine the measurements of the diversity and sensitivity of the benthic macroinvertebrate community with many traditional physical stream attribute measurements.

KREW believes the methods presented by Harrelson et al. (1994), the Stream Condition Inventory (USDA, 1998), and Herbst (2001) can be used to characterize and/or classify its streams. Each of these approaches are briefly summarized and then discussed with regard to the characteristics of headwater streams and KREW objectives. A subset of measurements from these four approaches is measured for KREW and discussed in section 5.3.

2.3.1 Harrelson et al. Classification

Harrelson et al. (1994) recommends the establishment of a longitudinal survey to establish pre- and post-treatment water surface slope, sinuosity and lateral channel migration. This protocol focuses on collecting baseline stream characteristic data on which to track future physical changes. KREW has installed permanent reference benchmarks from which both longitudinal and cross-section data is measured.

2.3.2 Stream Condition Inventory

Forest Service Region 5 hydrologists and fisheries biologists, in cooperation with the Pacific Southwest Research Station, developed the Stream Condition Inventory (USDA, 1998), commonly called SCI. It is intended to provide reliable information on streams that can be used by both physical and biological resource specialists to inventory and monitor stream conditions. Specifically, the information collected may be useful in identifying or quantifying key aquatic ecosystem components, in helping to assess and describe existing and potential conditions for aquatic ecosystems, and in responding to specific issue driven stream-monitoring questions. During pilot testing of the SCI, emphasis was given to third order streams and larger. Additionally SCI was tested mainly on low gradient (<2%) reaches with a high sinuosity, and its protocols work best for these stream types. When applying SCI to higher gradient stream types, additional attributes sensitive to site-specific conditions may need to be used. The SCI

protocol uses a hierarchical approach with two inventories applied at different spatial scales: the Field Extensive Inventory and the Field Intensive Inventory.

The Field Extensive Inventory is used to determine the overall condition and classification at a watershed scale using standard protocols. This procedure is meant to give a one time overall snapshot of the watershed. The Field Extensive SCI attributes include: large woody debris (LWD) count, counting pools including pool depth and depth at pool tail crest, pool substrate composition (v-star), stream shading, width-to-depth ratio, stream bank stability, presence of fish and other aquatic species, and classification of intermittent and ephemeral streams (Hopson, 2003).

The Field Intensive Inventory identifies the condition and classification of "sensitive reaches" and "survey segments" using standard protocols designed to be repeated over time with a reasonable level of statistical confidence through the use of monumented sites. A "sensitive reach" is the portion of a stream that is most likely to show change that relates to a study.

2.3.3 Herbst Physical Habitat Survey

Herbst (2001) designed a protocol to collect data that is a combination of physical habitat survey data and biological sampling of benthic macroinvertebrates. This section concentrates on the physical habitat survey and leaves the bioassessement portion of the protocol to be discussed in section 2.10. The protocol is described as it was developed for the California State Water Board, Lahonton Region. Each site is defined as a 150 m length study reach, located by GPS-UTM coordinates and elevation (near lower end of each watershed and usually above a flume or weir). The longitudinal distribution and length of riffle and pool habitats are first defined then used to determine random sample locations for benthic macroinvertebrates from both pool and riffle habitat.

2.4 Sediment

There are many degradational and aggradational sources of sediment in a watershed. The KREW study seeks to quantify sediment loads created by mechanical thinning and burning. For example, existing headcuts can produce large volumes of sediment that would not be a result of our treatments. We are establishing a pre-treatment average sediment budget by collecting sediment basin, headcut, road and upland erosion rates. This budget is compared with discharge, meteorology and post-treatment data to calculate erosion due to management. We have installed sediment catchment basins at each of the eight watersheds, annually we empty, weigh and analyze mineral and organic content. Additionally we are utilizing the Wepp and GeoWepp erosion models as a comparison of our data.

2.5 Turbidity and Suspended Sediment

Measuring stream turbidity is an effective way of estimating suspended sediment load. Turbidity is typically recorded in nephelometric turbidity units (NTU), an optical measurement of the amount of light that is absorbed by particles suspended in the water column. Lewis (1996) and others have

demonstrated the correlation between turbidity measurements and the amount of suspended sediment in the water column. Relationships can be developed through continuous turbidity monitoring in conjunction with suspended sediment sampling. Using the relationship between suspended sediment concentration (SSC) and turbidity it is possible to estimate suspended sediment yield for a watershed based on the continuous turbidity data.

2.6 Soil Characterization

Soil physical properties profoundly influence the growth and distribution of vegetation through their effects on soil moisture regimes, aeration, temperature profiles, soil chemistry, and even the accumulation of organic matter. These properties also influence erosion potential and the chemical composition of water that reaches streams. The most widespread result of management on the physical properties of soils may be inadvertent soil compaction during tree harvesting operations. Wildfires and hot areas within prescribed burns may result in a well-defined hydrophobic (water repellent) layer at the soil surface that may increase erosion rates. This heat-induced water repellency results from the vaporization of organic hydrophobic substances at the soil surface during a fire, with subsequent condensation in the cooler soil below (Fisher and Binkley, 2000).

Few studies have examined the effects of thinning on soil nutrient supply. Most have found little effect on net nitrogen mineralization, for example, which indicates that the nutrient supply per residual tree increases in proportion to the reduction in stocking (Beets and Pollock, 1987; Martinez and Perry, 1997). In some cases, net nitrogen mineralization may increase following the removal of a portion of the stand, providing a double boost to the nitrogen supply of residual trees (Prescott, 1997).

Soil can be divided into three phases: solid, liquid, and gas. The solid phase makes up approximately 50% of the volume of most surface soils and consists of a mixture of inorganic and organic particles varying greatly in size and shape. The size distribution of the mineral particles determines the texture of a given soil. Soil texture has major effects on forest growth, but these effects are indirect, manifested through the effect of texture on features such as water-holding capacity, aeration, and organic matter retention. Soil structure refers to the aggregation of individual mineral particles and organic matter into larger coarser units (e.g., platy, prismatic, columnar, angular blocky, subangular blocky, granular, crumb, single grain, and massive). This aggregation generally reduces bulk density and increases water movement and aeration. Field descriptions of soil structure usually give the type or shape, class or size, and degree of distinctness in each horizon of the soil profile. Soil organisms, mineral chemistry, freezing and thawing, fungal hyphae and roots, and tree species all influence soil aggregation (Fisher and Binkley, 2000).

Bulk density is the dry mass (<2 mm material) of a given volume of intact soil. Well-developed soil structure increases pore volume and decreases bulk density. Pore volume refers to that part of the soil volume filled by water or air. The particle density of most mineral soils varies between 2.60 and 2.75, but the bulk density of forest soils varies from 0.2 in some organic layers to almost 1.9 in coarse sands. Soils high in organic matter have lower bulk densities than soils low in this component. Soils that are

loose and porous have low bulk density, while those that are compacted have high values. Bulk density can be increased by excessive trampling by grazing animals, inappropriate use of logging machinery, and intensive recreational use, especially in fine-textured soils. Increases in soil bulk density are generally harmful to tree growth, can reduce seedling survival, and reduce water infiltration (Fisher and Binkley, 2000). On the other hand, increasing bulk density in dry, sandy soils can improve water holding capacity (R.F. Powers, personal communication, USDA Forest Service, Redding, CA).

Compaction by heavy equipment or repeated passages of light equipment compresses the soil mass and breaks down surface aggregates, decreasing the macropore volume and increasing the volume proportion of solids. Reductions in air diffusion and water infiltration often combine with increases in soil strength in compacted soils. Compaction occurs more frequently on moist soils than on dry soils and more often on loamy-clay soils than on sandy soils. The effects of compaction may be less permanent in fine-textured soils than in some coarse-textured soils because of swelling and shrinking as a result of wetting and drying (Fisher and Binkley, 2000).

The term infiltration is generally applied to the entry of water into the soil from the surface. Infiltration rates depend mostly on the rate of water input to the soil surface, the initial soil water content, and internal characteristics of the soil (such as pore space, degree of swelling of soil colloids, and organic matter content). Overland flow happens only when the rate of rainfall exceeds the infiltration capacity of the soil. Because of the sponge-like action of most forest floors and the high infiltration rate of the mineral soil below, there is little surface runoff of water in mature forests even in steep areas. When rainfall does exceed infiltration capacity, the excess water accumulates on the surface and then flows overland toward stream channels. High-velocity overland flow can erode soils. The litter layer beneath a forest cover is especially important in maintaining rapid infiltration rates. This layer not only absorbs several times its own mass of water, but also breaks the impact of raindrops, prevents agitation of the mineral soil particles, and discourages the formation of surface crusts (Fisher and Binkley, 2000).

The presence of organic matter in mineral soils increases their permeability to water as a result of increased porosity. Forest soils have a high percentage of macropores through which large quantities of water can move, sometimes without appreciable wetting of the soil mass. Most macropores develop from old root channels or from burrows and tunnels made by insects, worms, and other animals. The presence of stones increases the rate of water infiltration in soils because the differences in expansion and contraction between stones and the soil produce channels and macropores (Fisher and Binkley, 2000).

Losses of nutrients in fires result from the combined effects of five processes. The relative importance of these processes varies with each nutrient and is modified by differences in fire intensity, soil characteristics, topography, and climatic patterns (Fisher and Binkely, 2000).

1. Oxidation of compounds to a gaseous form (gasification)
2. Vaporization (volatilization) of compounds that were solid at normal temperatures
3. Convection of ash particles in fire-generated winds

4. Leaching of ions in solution out of the soil following fire
5. Accelerated erosion following fire

Fire oxidizes organic matter to form carbon dioxide and water, releasing tremendous amounts of energy as heat. Nitrogen in organic matter is oxidized to N_2 and various nitrogen oxides are lost from the system. Nitrogen losses are commonly proportional to the quantity of fuel consumed in a fire and the nitrogen content of that fuel. Calcium in organic matter is converted to calcium oxides and bicarbonates, which are lost in wind-blown ash or retained on site. Phosphorus in organic matter may be lost as a gas or released as barely soluble phosphate salts. Fires drastically alter the composition and activity of the soil biota, but little information is available on these changes. Despite the loss of nutrients in fires, nutrient availability to plants typically increases after fire as a result of heat-induced release of nutrients, reduced competition among plants, and perhaps sustained changes in soil conditions (such as temperature and water content). Fire physics largely determine fire impacts on forest soils.

The leaching of nutrients from soil after fire is influenced by the increased quantity of ions available, changes in uptake and retention by plants, adsorptive properties of the forest floor and soil, and patterns of precipitation and evapotranspiration. However, even in the most extreme cases, the extent of loss by this process is generally small relative to other loss pathways and the total nutrient capital (Fisher and Binkely 2000).

The supply of nutrient cations (calcium, magnesium, and potassium) generally increases following fire. This increase results from direct release from burning organic matter and from any increase in subsequent rates of organic matter decomposition. Heating may also directly alter soil exchange properties, causing cation and nitrogen release. The availability of calcium, magnesium, and potassium does not limit forest growth in most temperate ecosystems, so the effects of fires on losses or cycling rates of these cations are probably not important to ecosystem recovery and productivity in most cases (Fisher and Binkely 2000).

The availability of phosphorus limits production in many ecosystems around the world, yet the effects of fire on phosphorus availability have been poorly characterized. Phosphorus availability can either increase or decrease after fire, at least temporarily.

The concentration of soil ammonium generally increases greatly after fire, sometimes by an order of magnitude or more. Walker et al. (1986) demonstrated that soil ammonium may increase as a direct result of soil heating, and ammonium may also be added to soil in ash. Concentrations of ammonium may remain elevated as a result of both the increase in ammonium production and a decrease in ammonium consumption by plants and microbes. Nitrate concentrations sometimes rise over a period of weeks or months following fire. Immediate increases are generally slight due to the low vaporization temperature of nitric acid and the very low concentration of NO_3 nitrogen in ash. Net nitrification increases following fire in a wide array of ecosystems as a consequence of increased pH and availability of ammonium. Pulses of ammonium and nitrate availability are ephemeral, often lasting for only a few growing seasons or less. Nitrogen availability following fire depends on the quantity of nitrogen lost in the

fire, changes in rates of microbial mineralization after the fire, and competition between microbes and plants for mineralized nitrogen. Where burned areas are colonized by plants capable of symbiotic nitrogen fixation the cycling of nitrogen is accelerated; such plants require greater quantities of phosphorus than other plants (Fisher and Binkely 2000).

2.7 Water Chemistry

Understanding ecosystem processes is important in understanding the chemistry of water. Surface water chemistry is a reflection of atmospheric inputs, soil properties, and channel properties along with human use of an area. Our goal is to characterize the chemistry of atmospheric water, shallow soil water, and stream water within our watersheds. We expect to be able to characterize groundwater chemistry based on the stream chemistry during late summer when groundwater dominates these systems; we will not attempt to measure groundwater chemistry. Meadows and seeps provide much of the summer and early fall flows in these streams; we have considered but not implemented shallow wells in meadows for occasional chemistry measurements.

Soils provide ecosystem resiliency after disturbance due to their capacity to provide stored nutrients for regenerating vegetation (Dahlgren, 1998). The higher the cation exchange capacity of a soil, the greater is its capacity to resist changes in the pH of the soil solution (Brady & Weil, 1996). Stream water chemistry is a close reflection of soil water chemistry. The weathering of the parent rock, the biological inputs, and meteorological events all influence the chemical soil attributes. Land use activities that affect soil properties and processes can also affect the chemistry of the stream (Brooks, 1997). The impacts of land use on water quality would best be understood by measuring the chemical attributes of the soil.

The chemistry of soils is complex, involving inorganic reactions between solid phases (including minerals, mineral surfaces, and organic matter), the liquid phase (near surfaces and in the bulk soil solution), and an incredible diversity of soil organisms. The soil solution is supplied with chemicals from atmospheric inputs and from the solid phases, and is depleted by processes of plant uptake and movement into the solid phases. Soil solutions contain dissolved chemicals, and many of these chemicals carry negative charges (anions) or positive charges (cations). The major soil cations include sodium, potassium, calcium, magnesium, and sometimes aluminum. The processes of soil solution chemistry and plant uptake interact with many other processes in forest ecosystems; this larger picture is called biogeochemistry. Biogeochemistry focuses on ecosystem productivity and nutrient cycling and examines the interactions among geology, chemistry, and biology (Fisher and Binkley 2000).

The productivity of forests depends on the supply of nutrients available within the soil for plant use. High nutrient concentrations lead to rapid growth. The flow of nutrients through the ecosystem involves oxidation and reduction reactions in which nutrient flow from the soil into trees is commonly greater than the annual input of nutrients into a forest. However, this flow is only a tiny fraction of the total pool of nutrients in the soil. The annual decay of litter from leaves and roots provides most of the

nutrients used by plants in a given year. However, the quantity of nutrients stored in the floor of most forests is either accumulating or in a steady state until a fire or another disturbance creates drastic losses. Thus the increase in nutrient content of the accumulating forest biomass must come from annual atmospheric deposition, mineral weathering, and from a declining pool of nutrients in slowly decomposing soil humus which is associated with the release and consumption of energy (Fisher and Binkely 2000).

2.8 Vegetation

Plant species respond differently to treatments, whereas some species benefit by disturbances such as prescribed fire, others may be adversely affected. Information from studies concerning management treatment effects on the plant community is probably sufficient; however, how the treated plant community in turn affects the watershed ecosystem is a critical link that has not been well-examined. The first logical step in understanding what role vegetation plays in a treated watershed is to quantify how the vegetation responds to the treatments. Some assumptions can then be made about how the quality of the vegetation response to treatment affects the quality of the watershed response.

A vital component of the whole watershed ecosystem is the riparian (near-stream) zone. To understand the dynamics of the aquatic ecosystem, it is necessary to understand the ecology of the riparian system that connects the stream to the vast upland region. The riparian zone acts as a buffer for the aquatic ecosystem of the stream, controlling the movement of chemicals and sediments into the stream (Lowrance et al., 1984). Riparian zones are probably best described as the zone of interaction between the aquatic and terrestrial (upland) environments, encompassing an area that begins at the edge of the water and extends out to the limits of flooding and up into the canopy of vegetation along the stream (Gregory et al., 1991). Stream channels change path and velocity frequently, and the riparian zone represents a continuum of soil moisture levels, from saturated to dry. These dynamic characteristics produce a complex plant and animal community that comprise much of the diversity of forests, and continue to change as the channel progresses downstream (Vannote et al., 1980). In the Sierra Nevada, riparian zones are particularly narrow and make up a relatively small proportion of the whole watershed (Kattlemann and Embury, 1996). This narrow riparian zone likely makes Sierra streams more sensitive to changes in the surrounding upland environment, than many other North American stream systems such as those in the Pacific Northwest or Eastern Deciduous Forests.

Decades of interest in the effects of fire and logging on upland communities have produced a solid base of information (Ansley and Battles, 1998; Vankat and Major, 1978; Biswell et al., 1966) for upland communities or forests as a whole. However, very little is known about what effect these practices have specifically on riparian ecosystems, through either direct application or erosion from adjacent, affected uplands. Information of this kind is particularly lacking for forests of the Sierra Nevada. In a study on the Lassen National Forest in the northern Sierra, Russell and McBride (2001) demonstrated that fire had a much smaller impact on stand composition than did proximity to water. A study in the Klamath range in northern California, found that fire return intervals were generally longer in riparian zones than

uplands; the author noted however that intervals were quite variable and sometimes as frequent in the riparian as the upland (Carl Skinner, personal communication). Brosofske et al. (1997) varied stream buffer widths for mechanical treatment in western Washington; they concluded that harvesting in adjacent uplands can alter the microclimate of the riparian zone.

In addition to the role of the riparian zone, it is important to understand how the plant community as a whole responds to treatment on the watershed. Included in the community may be rare and endemic species, or important timber species that respond differently to management treatment. The Sierra Nevada sustains a very high quantity of rare and endemic taxa, and is perhaps more prone to species loss or endangerment due to management activities. For its size, the Sierra is predicted to be the most floristically diverse region in all of the United States and Canada, maintaining approximately 3500 vascular plant species, 405 of which are endemic to the range. The Kings River basin, where this study will take place, is home to 56 plant taxa that are considered rare and 150 that are endemic to the Sierra; this is the second highest quantity of rare and endemic taxa of all major drainage basins in the range (Shevock, 1996). A large portion of the Sierra Nevada is land that is maintained by the Forest Service, so understanding how to properly manage the land is crucial for the maintenance of these many species.

The following people contributed advice and expertise to the design of the vegetation monitoring: Michael Barbour, University of California, Davis; John Vankat, Professor Emeritus, Miami University, Oxford, OH; Dave Weixelman, Adaptive Management Services, USDA Forest Service, Nevada City, CA; Steven Greco, University of California, Davis

2.9 Fuel Loading

The amount and condition of fuels in a forest stand can have significant effects on fire intensity and frequency, which in turn affect forest organisms differently. Agee et al. (1977) quantified fuel loads and percentage reduction in fuels, resulting from prescribed burning in different seasons of a mixed-conifer forest. Prescribed fire reduced fine fuel loads by 60-70% of the pre-treatment loading; pine litter and duff were reduced the most, while white fir fuels were more compact and burned with less intensity. Stohlgren (1988) documented a large amount of variation in litter fall and decomposition among plots and tree species in a mixed-conifer forest stand in Seqouia National Park. Knapp and Keeley (2001) provide more background material on this topic in their Study Plan for the Fire/Fire Surrogate Study. Adequate characterization of the variability in fuel loads is necessary for pre- and post-treatment comparisons and for input to fire models. It may be possible to correlate certain observed effects in nutrient flow, stream biotic composition or floral and faunal composition with differences in fuel loading. Characterizing the fuel loading can also contribute to conclusions about the effectiveness of prescribed fire versus mechanical thinning.

2.10 Stream Invertebrates

Aquatic insects and other invertebrates are central to the function of stream ecosystems, consuming dead organic matter (wood and leaf debris) and algae, and providing food for higher trophic levels (fish and riparian birds, spiders, bats, lizards, etc.). These organisms also have varying degrees of pollution tolerance and so may be used as indicators of water quality and habitat conditions. For example, distinctive shifts in the structure and function of the aquatic invertebrate community can often be detected above and below a pollution source. The use of the stream invertebrate fauna in evaluating stream ecosystem health is known as bioassessment (Rosenberg and Resh 1993). Bioassessment uses representative samples of benthic (bottom-dwelling) invertebrates to determine the relative abundances of different taxa, feeding guilds, and pollution indicators, as well as diversity, to develop a quantitative measure of the ecological health of streams. Comparisons of sites or times in watersheds affected by forestry practices to reference, unperturbed sites or times, then, permits the impacts of forest practices to be quantified (Rosenberg and Resh 1993, Davis and Simon 1995).

Not complete, to be added before review workshop.

2.11 Stream Algae

To be added.

3. Objectives

The Kings River Experimental Watershed (KREW) is designed to increase knowledge about pattern and process on the landscape--headwater stream ecosystems and their associated watersheds in the Sierra Nevada of California. It is also designed to address the following management questions and information gaps about mechanical thinning and prescribed fire effects on stream ecosystems (U.S. Department of Agriculture, Forest Service, 2001).

1. What is the effect of fire and fuel reduction treatments (i.e., thinning of trees) on the riparian and stream physical, chemical, and biological conditions?
2. Does the use of prescribed fire increase or decrease the rate of erosion (long term versus short term) and affect soil health and productivity?
3. How adequate and effective are current stream buffers at protecting aquatic ecosystems?

KREW exists within the larger Kings River Sustainable Forest Ecosystem Project, which is a collaborative effort between the Pacific Southwest Research Station and the Sierra National Forest to return two watersheds to historic forest conditions (1800s) using mechanical thinning and prescribed fire. Healey (1998) discusses that none of the watershed management experiments in the Pacific Northwest incorporates all four essential principles of ecosystem management: (1) organized around naturally bounded ecosystem units; (2) based on a mix of environmentally sustainable human activities; (3) focused on ends rather than means; and (4) employs adaptive experimentation and learning. The Kings River Project (KRP) incorporates these principles.

Streams are highly variable over space and time, and exhibit high degrees of connectivity between systems longitudinally, laterally, and vertically (Naiman and Bilby, 1998). Using watersheds as units for ecosystem management allows for a logical emphasis on the linkages between land and water. These linkages have generally been ignored in the design of resource legislation and management agencies (Healey, 1998). Human actions jeopardize the biological integrity of water resources by altering one or more of five principal factors: physical habitat, seasonal flow of water, the food base of the system, interactions within the stream biota, and chemical contamination. These features are connected physically, chemically, and biologically (Karr, 1998). KREW recognizes that measurements of physical, chemical, and biological variables are necessary to accomplish a holistic watershed study and has carefully tried to include those attributes critical to detect change in both patterns and processes in atmospheric inputs, watershed uplands and riparian areas, and in stream channels. The challenge is to develop an integrative experimental approach that is also financially feasible to maintain for 12-15 years.

3.1 Stream Discharge

Measuring physical, biological, and chemical stream attributes is a primary objective. Accurate stream discharge data at frequent intervals is critical to characterize the variability of stream systems. Small headwater streams in the southern Sierra are highly variable. Accurate discharge data are necessary to calculate flow-weighted chemical and sediment concentrations and develop accurate loading estimates.

Changes in total annual runoff and the timing of spring runoff will be important for understanding any effects from harvesting and prescribed burning. The timing of discharge peaks may also affect the stream macro-invertebrate community, a biological attribute being measured by KREW.

The KREW study is investigating nutrient cycling in a forest environment and the main point of egress for nutrients is down streams. To determine the net flux of a nutrient out of the system both stream discharge and nutrient concentration must be accurately measured. Accurate low flow discharges are important because nutrient concentrations are highest in low flow periods (preliminary data).

Recent papers (Lundquist and Cayan, 2002) have started to look at diurnal discharge cycles as diagnostic for major changes in a watershed and/or in the meteorology of a region. To investigate these questions one needs precise flow data on a short time step (1 hour or better).

KREW staff drew up a conceptual model indicating how management activities affect forest processes and how these processes in turn affect stream discharge (Figure 3.1).

3.2 Meteorology

KREW seeks to collect data that will be useful to both current and future researchers and that will support the goal of process and effects modeling exercises. With this in mind, the following meteorological variables will be measured or calculated from measurements: wind direction, wind speed, wind run, relative humidity, temperature, solar radiation, precipitation, snow depth, and snow water equivalence (SWE).

3.3 Stream Channel Characteristics and Geomorphology

KREW is establishing a pre-treatment record of physical stream channel conditions for each of its eight watersheds. We utilize longitudinal, cross-section, large woody debris, and pool fine storage information from which changes in the stream channel can be quantified.

3.4 Sediment

KREW will quantify the sediment produced by thinning and burning management actions on a watershed scale. In the KREW study we are measuring the mass of sediment that the watersheds produce under existing conditions, pre-treatment. The pre-treatment sediment basin, sediment fence (upland and road), and headcut data track the degradation and aggradations of the soils within our watersheds. Our post-treatment data will provide management related sediment production rates on a kg/ hectare/year basis (Figure 3.4).

3.5 Turbidity and Suspended Sediment

By comparing pre-treatment and post-treatment continuous turbidity data it will be possible to see the effect mechanical thinning and prescribed fire have on suspended sediment. However, unless the correlation between turbidity values and suspended sediment concentration (SSC) can be established it

will be difficult to quantify the change in suspended sediment yields due to the treatments. KREW seeks to develop a turbidity monitoring and suspended sediment sampling protocol that help establish the relationship between turbidity and sediment yields. Suspended sediment concentration data can be converted to total suspended sediment (TSS) using stream discharge. Comparing TSS data before and after the treatments would be a very effective measure of treatment effects.

3.6 Soil Characterization

The objective for the physical soil characterization is to compare pre-treatment and post-treatment measurements to determine the effect of the treatments on physical soil attributes. We want to measure a reasonable number of watershed grid points to adequately characterize the variability in soil attributes of interest. Soil characteristics are important for understanding watershed condition, changes in ecosystem processes, and explaining changes that might be seen in stream conditions; however, not everything of interest can be measured. The attributes selected are those thought to be important for understanding the effects of mechanical thinning and prescribed fire; evaluating atmospheric pollutants and climate change are secondarily of interest. Their selection is based on years of experience working with forest soils, and the desire to be compatible with ongoing soil work in both the eastern Sierra Nevada (Joint Fire Science Program project 00-2-05) and the two Fire and Fire Surrogate Study locations in the northern (Blodgett Experimental Forest, Joint Fire Science Program project 99-S-1a) and southern Sierra Nevada (Kings Canyon National Park, Joint Fire Science Program project 99-S-1a).

3.7 Water Chemistry

KREW's objective is to characterize the variability of water chemistry both on an annual and seasonal basis, thus we have to collect samples at an adequate frequency. Knowledge of variability aids in recognizing changes in chemical characteristics following treatments. An inventory of the snowmelt chemistry will help evaluate the atmospheric contribution to water chemistry. An inventory of the soil water chemistry will evaluate how the chemical changes as the precipitation moves through the soil. An inventory of the ion activity in the soil will give an understanding of the nutrient budget as well as the buffer capacity of the areas soils. With study sites containing a snowmelt collection system, soil water collection system, and an ion exchange resin (IER) monitoring system, we are gaining insight into these areas. The IER lysimeter technique has been employed in past research studies (Susfalk and Johnson, 2002; Kjonass, 1999) and has proven to be a good indicator of plant-available nutrients. The exchange mechanism of the IER is thought to mimic the nutrient uptake action of plant roots (Susfalk and Johnson, 2002). Snowmelt samples and soil water samples both provide temporal variability of one soil type. By employing the soil IER lysimeter system, we are able to add the dimension of spatial variability.

3.8 Vegetation

The major objective of the vegetation portion of the KREW, is to examine the effects of mechanical thinning, prescribed fire, and a thinning and fire combination implemented on small watersheds, on the vegetation within the watershed. A secondary objective is to determine the effects of treatments on riparian vegetation, in particular, and characterize the transition from riparian to upland vegetation.

It is expected that thinning, prescribed fire and the combination treatment, all will improve tree growth, recruitment and survival during the field season following implementation. It is further expected that treatments will initially reduce canopy coverage, but will likely increase herbaceous and shrub layer coverage, including a higher importance of early-successional species. It is less clear whether, or to what extent, treatments will differentially affect these vegetation attributes, and for how many seasons those trends will continue. Ultimately, the Sierra National Forest would like to re-create forest conditions present prior to European settlement (circa 1850). These treatments may provide clues as to which may help the Forest achieve that goal most accurately and prudently (Figure 3.8).

4. Study Area and Management Treatments

KREW is located on the North Fork of the Kings River that drains into the San Joaquin River Basin. It is located in the Kings River Project, Sierra National Forest. The Kings River Project was implemented in 1994 with an initial dedication of 26,000 ha (64,000 acres) now expanded to the full Dinkey Creek and Big Creek watersheds (61,000 ha/150,000 acres). The Project is a joint effort of the Sierra National Forest, the High Sierra Ranger District, and the Pacific Southwest Research Station.

4.1 Study Area

Two sites are being developed: (1) Providence Site has three headwater streams of Providence Creek and one headwater stream of Duff Creek in the Big Creek drainage and (2) Bull Site has three headwater streams of Bull Creek from the Dinkey Creek drainage and one headwater stream from Teakettle Creek in the Kings River drainage (Figure 4.1-1). These watersheds contain mixed conifer trees at 1524 m (5000 ft) and 2134 m (7000 ft) elevation, respectively. Each Site consists of four headwater watersheds. Within a Site, one watershed will serve as the control (no treatment), one will have a prescribed fire treatment, one will have a mechanical harvest treatment, and one will have both mechanical harvest and prescribed fire treatments. They range in size from 49 ha (120 acres) to 228 ha (562 acres); a size that can be consistently treated. Characteristics of the experimental watersheds are listed in Tables 4.1-1, 4.1-2, and 4.1-3. A goal was to find headwater watersheds that were as similar as possible for certain characteristics; however, landscapes such as these will never be completely homogeneous nor exactly similar.

The Providence Site is at a lower elevation than the Bull Site and contains land that is owned and managed by Southern California Edison (Figure 4.1-2). The Bull Site adjoins PSW's Teakettle Experimental Forest, which provides a unique opportunity (Figure 4.1-3). The Teakettle Experimental Forest was established in 1936 as a hydrologic study area. While fire suppression and grazing occurred on this area no known timber harvesting took place. Weirs and associated ponds were constructed on five headwaters watersheds and historic data exist for these streams. Using one of these instrumented watersheds for a control allows us to utilize a longer pretreatment record for stream discharge and have more of a true control (i.e., no previous timber harvesting).

Table 4.1-1—*Attributes of the streams on each of the eight KREW watersheds.*

Watershed code	Channel length (m)	Elevation range (m)	Length of meadow (m)	% Channel in meadow
P301	1766.3	1790-2005	289.0	16.4
P303	1132.9	1730-1865	0.0	0.0
P304	793.9	1760-1895	70.5	8.9
D102	1754.7	1485-1885	44.5	2.5
B201	595.9	2145-2325	548.1	92.0
B203	2062.2	2185-2420	590.0	28.6
B204	2155.7	2195-2395	1329.4	61.7
TK1	3170.5	2050-2415	726.7	22.9

Table 4.1-2—*Attributes of each of the eight KREW watersheds.*

Watershed code	Watershed area (Ha)	Elevation range (m)	Meadow area (Ha)	Length of road (mi)	Dominant soil type (% cover)
P301	99.2	1790-2115	1.8	0.5	Gerle-Cagwin 62%
P303	132.3	1730-1990	0.1	1.0	Shaver 66%
P304	48.7	1760-1980	0.1	1.0	Shaver 55%
D102	120.8	1485-1980	0.4	1.0	Shaver 48%
B201	53.0	2145-2380	1.6	1.4	Cagwin 67%
B203	138.4	2185-2490	3.4	2.6	Cagwin 80%
B204	166.9	2195-2490	8.3	3.1	Cagwin 98%
TK1	227.7	2050-2465	6.6	0.2	Cagwin 94%

Table 4.1-3—*Vegetation cover type summary for the eight KREW watersheds. Coverages represent percent land area within each watershed. Meadow area is not included here, but is covered in detail in tables 4.1-1 and 4.1-2. Abbreviations of vegetation types are the following: SMC – Sierra Mixed-Conifer, PPN – Ponderosa Pine, RFR – Red Fir, LPN – Lodgepole Pine, MCP – Montane Chaparral, MHC – Mixed Chaparral, AGS – Annual Grass, BAR – Barren.*

Watershed code	% Cover of each vegetation type								
	SMC	PPN	RFR	LPN	MCP	MCH	AGS	BAR	Total
P301	82.1				6.2			9.8	98.1
P303	94.6							5.4	100.0
P304	99.6							0.1	99.7
D102	76.3	11.4			0.8	11.2		0.0	99.7
B201	92.2							3.5	95.7
B203	47.0		43.7		0.8			7.2	98.7
B204	47.8		41.1	1.0				2.6	92.5
TK1	78.3		19.0		0.5		0.4	0.9	99.1

By the fall of 1999 four areas (also referred to as sites) were being evaluated as potential areas in which to conduct the watershed study. The four areas were the headwater tributaries of Blue Canyon, Providence, Turtle, and Bull creeks. Each area had at least four potential perennial streams that appeared to meet the study criteria.

KREW staff took water samples and performed crude flow estimates monthly for one year. This elucidated the fact that at Providence, Bull, and Blue Canyon sites one or more of the selected streams were not perennial. Chemistry tests on these same streams revealed that several streams at the Blue Canyon site had high sulfate concentrations and had high temperatures (11° C) all winter. Further searching at the Bull, Providence, and Blue Canyon sites located alternate streams that could replace those being eliminated because they were not perennial. From a scientific standpoint theses sites could have worked for the study, although Blue Canyon was borderline.

We then began discussions with the Sierra National Forest about implementation of thinning and burning treatments on the four sites. The district silviculturist determined that there was sufficient timber to support an economical thinning at all four sites. The fuels management officer (FMO) ruled out the Blue Canyon site because there is a housing tract above it and there was no way to safely underburn the watersheds. The FMO said he could burn all four Turtle watersheds simultaneously, but based on previous experience at the site he could not burn one watershed and keep fire out of the adjacent watershed because of steep terrain. Thus practical considerations eliminated two of the sites for burning.

After the discussions with the Sierra National Forest it was decided that the Providence and Bull locations would be suitable for the watershed experiment. For the Providence Site, Duff Creek was chosen to replace the one stream that was not perennial. For the Bull Site, Teakettle #3 stream, on the east side of Patterson Mountain., was chosen as a replacement. Teakettle has an existing weir and approximately 15 years of flow data.

**With this configuration KREW maintained the ability to construct two integrating gaging stations, one of which would integrate three Bull streams and one of which would integrate three Providence streams. Neither of the replacement streams (Duff and Teakettle #3) flow to a location appropriate for an integrating gaging station. *The benefits and costs of the integrating stations will be discussed as part of the study design review process*.

4.2 Management Treatments

Table 4.2-1 describes the management treatments that have been assigned to each experimental watershed at this time. Details of actual implementation remain to be worked out, as some sites require coordination with other Kings River Project experiments.

***Mechanical thinning would usually have the slash piled by tractors and burned in piles. If we want a thin only with no burn, we have to decide what to do with the slash.*

***The Framework allows prescribed fire to back into stream management areas but not be lighted. Because the experiment wants to evaluate the effect of fire on these near stream areas, we will likely be*

lighting in the stream management areas up to some small distance from the edge of the stream bank (to be determined).

Table 4.2-1—*Management treatments by watershed and issues to be resolved.*

Watershed code	**Treatment**[a]	**Notes**	**Forest bird plot**[b]
Providence Site			
P301	Thin & underburn	6-yr plantation in lower piece. Hand release around plantation trees. Contains SCE land--plan meeting. Loose some area for treatment because of grid.	Yes, Providence. This piece in stand 235 will not be thinned (make a plant aggregation). Summit Meadow adjoins.
P303	Underburn	Ramiro & Dave need to walk lower edge of Forked Meadow grid to see if can hold burn line without causing erosion. If FM grid not burned, loose some area for treatment. Owl FR021.	Yes, Providence, Lower Providence, & Forked Meadow . L. Prov. grid needs to be moved into watershed boundary. Could change to burn FM?
P304	Control, no treatment	Plantation will require hand treatment	No
D102	Thin[c]	Some area is tractor ground; much is too steep. 50% SCE land--plan meeting. Need to decide how to treat slash. Owl FR122.	No
Bull Site		Old forest emphasis area. Yosemite toad.	
B201	Thin[c]	Jimmy Jean mine being reclaimed. Complete in 2003; buildings come out.	No
B203	Underburn	Upper edge in Teakettle E.F. Carolyn talk with M. North for ok. Owl FR084 10% HRCA.	No
B204	Thin & underburn	Has wet area that probably can not be thinned. Upper edge in Teakettle E.F. Carolyn talk with M. North for ok. Owl FR084 30% HRCA.	No
Teakettle TK3	Control, no treatment	None	No

[a] Underburn likely will not follow Framework specifications.
[b]Requires coordination for treatments.
[**c]*Requires decision on how slash will be treated.*

5. Methods (include literature references, sampling diagrams, location of detailed protocols for data collection)

The ecosystem attributes that are currently planned for KREW and the spatial and temporal frequency at which they will be measured are summarized in Table 5.0-1.

Table: 5.0-1—*Summary of KREW physical, chemical and biological measurements.*

Document section	Measurement category	Measurement	Frequency	Spatial unit
5.1	Stream Discharge	Measurement by ISCO 730 Bubbler®, Aquarod®, and Telog	15 minutes	1 point / watershed
5.2	Meteorology	Temperature, Relative humidity	15 min. average, 24 hr. maximum, 24 hr. minimum	2 points / watershed site
		Solar radiation	15 min. average flux, 24 hr. totalized flux density	2 points / watershed site
		Wind speed, Wind direction	15 min. sample, daily max. 10 sec. gust speed and direction	2 points / watershed site
		Wind run	24 hr. total	2 points / watershed site
		Snow depth	15 min. sample	2 points / watershed site
		Precipitation / Snow water equivalence	1 min. average every 15 minutes, daily change in total	1 point / watershed site
5.3.1	Stream Channel Characteristics and Geomorphology: Baseline Data	Surveyed longitudinal profile data: thalweg, water surface, bankfull indicators	One-time measurements that may be repeated after treatments.	Entire length of each stream
		Transect data: pebble counts to determine D50 particle size, bankfull width, bankfull maximum depth, flood prone area width, bankfull mean depth		10-30 temporary transects / stream
5.3.2	Stream Channel Characteristics and Geomorphology: Permanent Study Reaches and Cross-sections	Stream Condition Inventory:	Twice before treatment and for at least the first three years after treatment.	
		Sensitive reach measurements: temperature, bankfull, LWD count, pebble count, 3 monumented cross sections, gradient (at each cross-section), also width / depth ratio and entrenchment at each monumented cross-section plus an additional 5 locations		Entire length of each stream
		Survey segment: habitat type ,pool count, maximum pool depth, percent fines in the pool tail, whether or not wood formed the pool, 50 transects to evaluate: bank stability, shade, bank angle, aquatic fauna		Lowest 1000m of each stream, unless the stream is shorter than 1000m than the entire stream length is used

Document section	Measurement category	Measurement	Frequency	Spatial unit
5.3.2	Continued… Stream Channel Characteristics and Geomorphology: Permanent Study Reaches and Cross-sections	Herbst Physical Habitat Survey Reach Data: habitat type (pool / non-pool), stream temperature, pH, conductivity, turbidity, flume size and stage, slope at 4 points in reach spaced at 25m, photos upstream and downstream at each slope point Transect Data: wetted width, bank cover (both banks), bank angle (both banks), vegetative shading (both banks and upstream and downstream), stream depth and velocity (5 points per transect), cobble embeddedness (25 cobbles total)	Annual and concurrent with invertebrate sampling.	One 100 m reach / stream 10 transects / reach
5.4	Erosion and Sedimentation	Sediment load – wet volume Also, a sub-sample is analyzed and results are extrapolated to estimate the total dry volume and mass, percent organic versus inorganic, and size class distribution of inorganic fraction	Annual	1 sediment basin / watershed (exceptions being B203 and B204 which have no basin)
5.5	Turbidity and Suspended Sediment	Measurement by Forest Technology Systems DTS-12 Suspended sediment sampling via grab and ISCO 6712 automated sampler	15 minutes Storm based	1 point / watershed 1 point / watershed
5.6	Soil Characteristics	Field measurements (see Section 5.5)	Once before and once after treatment	Subset of points in 150m grid that has been densified in B201 and P304 watersheds
5.7.1	Shallow Soil Water Chemistry	Prenart Vacuum Lysimeter Each Prenart system captures soil water at six locations with samples taken from two depths at each location: 13 cm and 26 cm, for a total of 12 samples. Resin Lysimeters buried at 13cm depth	Integrated samples are retrieved and sent for analysis every 2 weeks during wet season. Annual	Providence Site has one Prenart system / watershed. The Bull Site has no Prenart systems. 2 / soil grid point and one at each Prenart sampling location.

Document section	Measurement category	Measurement	Frequency	Spatial unit
5.7.2	Snowmelt and Rainfall Chemistry	Resin throughfall lysimeters placed on ground surface Snow-melt collectors, co-located at each Prenart site. Six collectors sample throughfall precipitation and one is in an open canopy location, for a total of 7 collectors per Prenart system.	Annual Integrated samples are retrieved and sent for analysis every 2 weeks during wet season.	1 / soil grid point. 1 above each Prenart sampling location 7 collectors / Prenart system
5.7.3 5.7.4	Stream Water Chemistry	ISCO 6712 samplers Grab samples	Collection and retrieval schedule is based on discharge, season and current weather forecast. Difficult to summarize, please see section 5.6.3.	1 point / watershed
5.8	Riparian Vegetation	20 m Transect perpendicular to stream Herbs – % cover by species using 4 1X1 m quadrats located along transect line with 2 at stream bank. Shrubs – % cover by species using the line-intercept method at every 1m along the line. Trees - % cover, density and recruitment by species using a 10X20 m belt transect along the 20 m transect.	Annual	1 transect every 200 m, 5-10 transect per watershed
5.8	Upland Vegetation	20 m Transect at random azimuth Herbs – % cover by species using 4 1X1 m quadrats located along transect line with 2 at stream bank. Shrubs – % cover by species using the line-intercept method at every 1m along the line. Trees - % cover, density and recruitment by species using a 10X20 m belt transect along the 20m transect.	Annual	Watershed divided into equal-sized partitions, with 2 transects per partition, resulting in 6-12 transects per watershed. The beginning of the transect will be placed on existing soil grid points.
5.8 not included in document	Riparian Vegetation and Microclimate	CSUF graduate student thesis of Dana Nagy, major professor Dr. Ruth Ann Kern	2-year study	Only done at Providence Site

Document section	Measurement category	Measurement	Frequency	Spatial unit
5.10	Stream Invertebrates	30-cm wide D-frame net, 250-micron mesh Taxa identified to genus (a few only to Phylum, order, Family)	Annual	100 m reach / stream where 3 riffles and 3 pools are randomly sampled
5.11	Algae / Periphyton	USGS performed pilot study in 2002—awaiting results Community structure Rock scrapings Biomass (measured as chlorophyll-a, pheophytin-a, and ash-free-dry mass)	Annual *(not sure about long term inclusion)*	100 m reach / stream used for sampling, co-located at a riffle with the invertebrate reach.
Not included in document	Fish	CSUF graduate student thesis of Nicholas Basile, major professor Dr. Steven Blumenshine	Annual *(not sure about long term inclusion)*	Only found at Bull Site

5.1 Stream Discharge

In this section we discuss location selection for flumes, weirs, stage recording design criteria, and stage measurement instruments. Seven new flume sites were constructed. At the Teakettle (T003) site the existing weir was used for discharge measurements. At the Providence Integrating watershed (P300) a new concrete weir was constructed. For measuring discharge at the Bull Integrating watershed (B200) no in-stream construction occurred; a flow meter will be used at a monumented cross section to develop a rating curve that correlates discharge with stage.

5.1.1 Site Selection for Flumes

A variety of techniques are used at KREW depending on the stream geomorphology, discharge, or existing structure. An ideal site for KREW is where a small flume, large flume, and sediment basin are co-located. Optimal discharge measurement is through the use of flumes that allow an accurate conversion of stream water level to total discharge. The flumes had to be located within 500 m (1640 ft) of the stream confluence or the area of the contributing watershed became too small to fit the study criteria. KREW staff tried to find stream reaches that met the Water Measurement Manual (USDI, 1967) criteria for a good flume site, but straight flat sections 20 times the channel width did not exist. KREW staff selected small flume sites where the stream was naturally narrow; usually this constriction was created by bedrock or several large boulders. These small flume locations were within 30 m (98 ft) of a relatively long, flat stretch that was appropriate for the large flume. Sediment catchment basins were located in natural deposition areas of the channel immediately below the downstream flume. On five of the seven streams selected for flume construction, the small flume is upstream of the larger flume making it crucial that the small flume does not disrupt flow patterns for the large flume or precipitate changes in channel morphology (Table 5.1-1).

Table 5.1-1 - Seven *flume site characteristics.*

Description	Flume throat width	Date constructed (month/year)	Installers	Flume wall height (cm, in)	Stage Recording Device
P301 Small Flume	8 cm (3 in)	9/2000	SE, AK	35.6 cm (14 in)	ISCO® Bubbler
P301 Large Flume	61 cm (2 ft)	10/2000	SE, RG, AK	91.5 cm (36 in)	AquaRod®
P303 Small Flume	8 cm (3 in)	9/2000	SE, AK	35.6 cm, (14 in)	ISCO® Bubbler
P303 Large Flume	61 cm (2 ft)	10/2000	SE, AK, RG	91.5 cm, (36 in)	AquaRod®
P304 Small Flume	8 cm (3 in)	10/2002	SE, RK, JA	45.7 cm, (18 in)	ISCO® Bubbler
P304 Large Flume	30 cm (1 ft)	10/2001	CJ, KD	91.5 cm, (36 in)	Telog®
D102 Small Flume	15 cm (6 in)	8/2001	ML, SE	45.7 cm, (18 in)	ISCO® Bubbler
D102 Large Flume	122 cm (4 ft)	9/2001	SE, AL, CJ	91.5 cm (36 in)	Telog®
B201 Small Flume	8 cm (3 in)	8/2001		45.7 cm (18 in)	ISCO® Bubbler
B201 Large Flume	61 cm (2 ft)	9/2001	SE, CJ, MS	91.5 cm (36 in)	AquaRod®
B203 Small Flume	15 cm (6 in)	9/2001	SE, ML	38.1 cm (15 in)	ISCO® Bubbler
B203 Large Flume	91cm (3 ft)	9/2001	CJ, SE	91.5 cm, (36 in)	AquaRod®
B204 Small Flume	15 cm (6 in)	10/2002	SE, RK	38.1 cm, (15 in)	ISCO® Bubbler
B204 Large Flume	122 cm (4 ft)	9/2002	JA, LR	91.5 cm, (36 in)	AquaRod®
Installers: SE-Sean Eagan, ML-Marie Lynch, JA-Jeff Anderson, CJ-Chad Johnson, AK-Aaron Keech, RG-Rob Grasso, AL-Andrea Lences, KD-Kevin Dougerty, MS-Maragret Shanafield, LR-Leah Roberts, RK-Ryan King					

5.1.2 Discharge Measurement Design Criteria

All the watersheds in the study have small irregular channels with random boulders that makes finding sections with uniform steady flow difficult. The Water Measurement Manual (USDI, 1984) lists many considerations for choosing a measuring device; these were considered most critical by KREW staff:

1) **Range of flow:** A year of monthly manual flow measurements determined that base flow was between 0.5 l/s (0.02 cfs) and 2 l/s (0.07 cfs). A goal was set to be able to accurately

measure a 50-year flood event. The 50-year event was determined by looking at an approximately 20-year record on four weirs at the Teakettle Experimental Watershed. Teakettle is adjacent to the Bull Site and about 15 km (9.3 mi) distance and 700 m (2296 ft) higher than the Providence Site. We know from regional meteorological data that the 20-year record contains several rainfall events in the 10 to 50-year magnitude range. These peak flows were then scaled to reflect different watershed areas. From this data it was determined that KREW needs to measure flow from 0.5 l/s (0.02 cfs) to 500 l/s (18 cfs) for the smaller watersheds and 1- 2,000 l/s (0.04-71 cfs) for the larger watersheds.

2) **Accuracy of measurement:** We wanted highly accurate measurements especially for low flows. Most weir designs are not accurate at 0.5 l/s (0.02 cfs).
3) **Ability to pass sediment and debris:** Because these flumes are in remote sites, having flumes clog could cause days of lost data. A design was chosen to minimize clogging.
4) **Environmental impacts:** Because KREW is studying macro-invertebrates and water chemistry it was important that channel alteration was minimized and that substrate and chemistry remain unaltered, except right at the flumes.
5) **Construction and installation requirements:** Some sites are not accessible by motorized vehicle so all material needed to be carried in. This limited individual piece size and prohibited designs that required more than 0.5 cubic meters (16 ft^3) of concrete.
6)
7) **Longevity:** The study is currently planned to last approximately 15 years, but the devices were designed to last 30 years or more.
8) **Standardization:** Using standard, tested devices was a priority so the general scientific community would accept our data.

5.1.2.1 Parshall-Montana Flumes

Parshall-Montana flumes were selected for discharge measurements(Figure 5.1-1). Parshall-Montana flumes are good at passing debris. Rand Eads at the Caspar Creek Watershed Study (USDA, 1998) had experience installing them at remote sites using lay people, which saves considerable cost over hiring construction companies. These flumes primarily rely on horizontal stream constriction to reach critical depth. This minimizes changes in channel hydraulics and puts less stress on the structure during high flow events. Finally, they do not require large upstream ponds to accurately measure flow.

Parshall-Montana flumes can measure flows of a 50-fold difference precisely and 100-fold less precisely. Each KREW stream has approximately a 500-fold difference between lowest and highest flow on a 20-year time span. This required installing two flumes, one large and one small, on each stream. In the case of our smaller streams (P301, P303, P304, B201) this allows precise flow measurements (from standard tables) from 0.75 l/s (0.03 cfs) to 900 l/s (32 cfs). We accept less precise, but still acceptable, measurements over the range from 0.3 l/s (0.01 cfs) to

1,400 l/s (49 cfs). KREW will be able to measure all flows given that the event is less rare than a 50-year event on both the low and high-flow ends. During severe drought years several of these creeks may loose surface flow during mid-afternoon in the late summer (i.e., peak period for evapotranspiration).

A Parshall-Montana flume is about half as long and half as heavy as a regular Parshall flume. The regular length Parshall allows for accurate measurement when the downstream end is submerged. Because our streams are steep, there is always a foot of elevation drop as the flow leaves the flume's throat; furthermore, the flow can expand out horizontally on both sides at least one flume width. For these reasons we will not submerge the downstream flume end and therefore feel we can use Parshall-Montana flumes. This decision saved us at least 30% on installation costs and minimized alteration to the stream. Using standard Parshall flumes, KREW staff would have needed to measure the head at two points, which would have added instrument costs and staff costs.

The flumes are constructed of structural fiberglass approximately 5 mm (0.2 in) thick (see appendix 18.1). Every flume has a metric staff gage located at the point of measurement. The flumes have bypass pipes to allow for future maintenance. Many of the flumes have stilling wells (Table 5.1-1). They were installed and leveled per techniques developed by Rand Eads at the PSW Forestry Science Laboratory in Arcata, California.

The small flumes' floors are 5-10 cm (2-4 in) above the thalweg that existed at construction. They are either 36 or 46 cm (14 or 18 in) tall. The wing walls are reinforced with 15-31 cm (6-12 in) thick concrete and rebar, and are at a 45-degree angle from the flow. During peak flow, the small flumes are designed to pass flow and debris over the top of the flume. During the first four years, overtopping has caused no small flume damage. At the flume's downstream end this overtopping creates a cascade with a head change of 0.5 to 0.7 meters (1.6 to 2.3 ft). Because the average wing wall is 3 m (9.5 ft) long, the depth of flow over the wall is typically 1 to 20 cm (4 to 8 in). Large flume wing walls are constructed from sheets of 6 mm (0.25 in) thick ABS plastic reinforced with channel aluminum stock.

During high flows, subsurface flow is less than the measurement error and therefore irrelevant to total flow; no effort was made to prevent flow under the large flumes. During the low flows of late August and September, subsurface flow may be a measurable percentage of the total flow. The small flume wing walls extend into the ground approximately 0.8 m (3 ft) or until they hit bedrock. There is an identical barrier going straight down from the mouth of the flume. This creates a fairly impermeable barrier below the stream channel approximately 4 m (13.1 ft) wide and 0.8 m (3 ft) deep. The effectiveness of these subsurface barriers is untested; a study could be done in late summer to determine if subsurface flow is being forced up to the surface. KREW expects the effectiveness to vary between sites.

5.1.2.2 V-Notch Weir Design Criteria

Two watershed sites utilize a weir structure for discharge measurement. These are the 90 degree V-Notch historic weir at Teakettle watershed (T003) and the 120-degree V-Notch weir constructed by KREW at the Providence Integrating watershed (P300). The base flows at these locations are two to four times higher than those found at the flumes, and the construction of a Parshall-Montana flume would have proved difficult and expensive.

Weirs operate by creating an upstream head behind the weir that can determine total discharge through the weir overflow. Unlike Parshall-Montana flumes, V-notch weirs can accurately measure discharge over the whole range of the weir blade height. This allows for the construction of a single weir as opposed to the two flumes required at other sites.

The weir at T003 was constructed in the 1940's and has been used to collect discharge data intermittently ever since (Kattelmann, 1989). To bring this weir back on-line very little maintenance was required. It consists of a 3 meter (9.8 feet) concrete dam with a steel 2.5 meter (4.7 feet) 90-degree weir blade. A second, rectangular weir blade is also installed in the dam as an overflow to prevent overtopping. The total basin area behind the weir is approximately 9 meters (29.5 feet) wide and 13 meters (42.7) feet long. Water level is measured in this pond to accurately measure discharge passing over the weir blade. The Teakettle weir can accurately measure flows ranging from 0.5 l/s (0.02 cfs) to 1,500 l/s (52.9 cfs).

The stream at the Providence Integrating location was too large to feasibly construct a flume. This site combines the flows from P301, P303, P304, as well as intermittent (not included in the study) P302. A flume would have been required capable of managing flows at least three to four times higher than those experienced at the smaller sites. Thus, a 120-degree V-Notch weir was constructed during the summer of 2005.

In order to prevent the structure from falling under the regulatory jurisdiction of the Army Corp of Engineers as a dam, the weir height could not exceed 1.4 m (4.5 ft) in height. A narrow, level reach was selected for installation. The total width of the weir is 5.5 m (18 ft). The foundation extends 0.8 m (3 ft) below the thalweg or until bedrock was hit to provide a firm foundation and prevent subsurface flows. The 120-degree stainless steel weir blade can measure flows from 0.5 l/s (0.02 cfs) to 1,500 l/s (52.9 cfs).

Both sites require yearly maintenance to remove sediment trapped behind the weir dam. The sediment from the Teakettle pond is weighed and recorded following the procedures established for stream sediment production. The P300 weir is just upstream from this watershed's invertebrate monitoring reach and the sediment starvation experienced downstream of the weir could influence the invertebrate populations.

5.1.2.3 Current Meter Discharge Measurement

The Bull Integrating watershed (B200) is the largest stream included in the watershed study. The difficulty and cost of constructing a flume or a weir at this site would have been extremely high. Diversion of the stream for concrete work would have been very difficult. For these reasons discharge measurements at this location are conducted using a current meter.

Flumes and weirs are designed with a built-in rating curve. For any given stage height a corresponding discharge is known. Without these measuring devices a rating curve relating stage height to discharge must be constructed. The rating analysis is the process in which the data from a series of discharge measurements are plotted and a mathematical relationship is constructed from the data (Kennedy, 1984). In order for this method to be successful, accurate discharge measurements must be made over a series of stage heights.

Discharge measurements at B200 are conducted using a Sontek® FlowTracker Handheld ADV® (FlowTracker) flow meter. This instrument uses acoustic waves to detect point stream velocities within an accuracy of 1%. Following standard USGS procedures, KREW staff measure discharge across an entire stream cross section. A metric staff plate has been installed at the site and each discharge measurement is correlated to the stage height at the time of measurement. As more discharge measurements are collected from both high-flow and low-flow conditions the rating curve becomes more accurate. With the rating curve developed, continuous stage height recordings can be converted to discharge using the rating relationship.

5.1.3 Stage Measurement Instruments

Parshall flumes require that stage be measured in the flume. Weirs require that stage be measured in the elevated head upstream of the weir. Rating curve discharge development requires that stage be measured in the stream at or near the discharge cross-section location. This can be done using floats, electrical pulses, ultrasonic sensors, submerged pressure transducers, and bubblers. The following criteria influenced the decision on which device to select:

- Ability to function in streams that freeze
- Low power requirements as using solar power
- Compatibility with a multifunction data logger and water sampler
- Established reliability record
- Ability to feed data to a sampler via a data logger and control the sampler
- Ability to work with telemetry
- Cost

Isco® 730 bubblers were chosen as the primary stage recording device because freezing does not destroy the instrument. Freezing does create data spikes if water has gotten in the bubbler line. The bubbler relays data to an Isco 6712 sampler, which also takes water samples

for chemical analyses. The Isco sampler and bubbler at each site receive power from a 12V DC system that uses a 50W solar panel and two or three, deep-cycle marine batteries connected in parallel. The solar panels are installed at a height sufficient to allow an unobstructed southern exposure (often in tall trees). By communicating with the sampler the Isco 730 bubbler allows KREW staff to take samples based on discharge. In 2003 telemetry was established at each site to enable the remote transmission of stage data to a computer at the Fresno office.

Bubbler line layout and how it enters the flume is an exacting process; poor layout leads to data spikes during high flows and freezing temperatures. Although precision is excellent, they do drift a little (5-10 mm, 0.2-0.4 in) and then require recalibrating. Precision is poor if the bubbler line has sharp bends or low spots. Desiccant beads must be replaced monthly.

Isco bubblers are currently installed to work on the small flumes and as the primary stage measuring devices at T003, P300, and B200. Stage height is logged by the Isco on 15 minute intervals. In addition each site has a backup stage recording device to provide readings should the bubbler systems fail (Table 5.1-1). Two backup systems are currently in use; Sequoia Scientific Aquarods® (Figure 5.1-2) and Telog Water Level Systems® instruments. At sites with flumes, the backup instruments are recording stage in the large flume configuration. Watersheds T003, P300, and B200 have the backup devices installed to record the same stage as the primary bubbler configuration.

Aquarods send an electronic pulse down a metal rod which arcs to an internal wire when the pulse hits the water surface; the time for the pulse's round trip is used to determine the distance to the water surface. They run on AA batteries and therefore are independent of the photovoltaic system. Aquarods do not break under freezing temperatures but the data are often spiked once the water surface is frozen. Aquarods record stage and water temperature at 15-minute intervals.

A main disadvantage of Aquarods is that it is impossible to know the status of the instrument without having a laptop and polling it. Also, they will not connect to the telemetry system. A field technician cannot determine how much power is left in the battery, so data can be lost if a battery dies prematurely.

Telogs utilize a submerged pressure transducer to measure water pressure and thus determine water depth. They have an internal factory installed battery that lasts for up to two years. The pressure transducers will break if the water they are submerged in becomes frozen, and for this reason they are only located at the lower elevation streams of the Providence Site. Telogs only record stage at 15-minute intervals. For a discussion of why other stage recorders where rejected see appendix 18-2.

5.2 Meteorology

Four permanent weather stations were installed for KREW: two at the Providence Site and two at the Bull Site. At each site, one station is located at the top of the site and another station exists at an elevation representative of the flume locations. This design was recommended by Danny Marks (personal communication, 2001) of the Reynolds Creek Experimental Watershed and will allow for interpolation of data over the topographic gradient. Data from Reynolds Creek shows the strong influence that elevation plays particularly in regards to precipitation measurements (Hanson, 2001). Since KREW expects small changes in response variables resulting from the treatments; it is therefore important that the meteorological input variables detect changes in the micro-climate across the topographic gradient to the same degree of accuracy.

5.2.1 Site Selection for Meteorological Stations

A number of factors were considered when KREW meteorological station locations were selected. The most important factor was selecting locations where representative data for the watershed site could be collected. Ideally each station's tower would have been located in a clearing at a distance of ten times the height of the nearest obstructions (Campbell Scientific, 1998). Trees approximately 50 m (164 ft) tall border many of the clearings in KREW. Therefore, it was not feasible to follow the siting recommendation since clearings with diameters of roughly 1 km (.6 mi) were not available. As a compromise, stations were positioned at the center of clearings with a diameter at least as wide as the height of the trees surrounding the clearing. Snow pillows were installed only at the high elevation locations and are situated on ground with less than a 5% slope as recommended by Garry Schaffer of the National Resource Conservation Service, Portland (personal communication, 2002). The snow pillow locations were visited during the winter preceding installation to insure that snow accumulation at the location would not be affected by vegetation or wind. An additional consideration was finding locations near established travel routes to other KREW sites. Exact meteorological station locations are provided in Table 5.2-1 and shown on Figures 4.1-2 and 4.1-3.

Table 5.2-1—*KREW meteorology station locations and elevations.*

KREW meteorology station		Location[a]		Elevation (m, ft)
		Easting	Northing	
Providence Site	Low elevation	0304205	4103425	1750, 5740
	High elevation	0305962	4103674	1984, 6510
Bull Site	Low elevation	0315448	4094247	2193, 7195
	High elevation	0316988	4092962	2461, 8075

[a] Locations given in UTM Zone 11S

5.2.2 Meteorology Instrumentation

Instrumentation at each station includes a 6 m (20 ft) tower, a precipitation gage, a telemetry antenna, and the two upper elevation locations also have a snow pillow. Installation was accomplished using the techniques described in the Resource Binder for KREW Permanent Weather Stations (Anderson, 2003). Radio antennas, like the one shown in Figure 5.2-1, are part of the telemetry system set up to transmit data from the station to the office in Fresno.

The 6 m (20 ft) tower supports various sensors, a solar panel, and two fiberglass enclosures. One enclosure houses the datalogger and radio telemetry equipment. The other enclosure houses the 12-V marine battery and charging system. Sensors on the tower measure relative humidity, temperature, wind speed, wind direction, wind run, solar radiation, and snow depth. Each tower is grounded to a rod embedded at least 1.2 m (4 ft) in the ground. Figure 5.2-2 shows the high elevation meteorological tower at the Providence Site. The precipitation gages are mounted on top of a large log embedded 1.3 m (4 ft) in the ground. The total height of the gage above the ground is 4 m (13 ft). Each gage utilizes non-toxic, propylene-glycol antifreeze that allows for measurement during winter months when frozen precipitation is common. In addition, a mineral based oil layer covers the liquid in the gage to help prevent evaporation of the standing water in the gage. A Tedea-Huntleigh load cell weighs the bucket in the gage, and from that measurement the depth of precipitation is determined. The collection orifice is encircled by an Alter-type wind shield. A significant amount of work has shown that undercatch is especially acute for unshielded gages during windy snow events; Alter-type shields have proven effective for improving collection (Hanson et al., 1996; Hanson 1999). Figure 5.2-3 shows one of the precipitation gage set-ups.

The two high elevation sites contain snow pillows for measuring snow water equivalence (SWE). Each site consists of a set of four, rectangular, steel bladders, 1.2 X 1.5 m (4 X 5 ft) each. These bladders are positioned adjacent to each other and plumbed together to form a 2.4 X 3 m (8 X 10 ft) pillow. The bladders are filled with the same non-toxic antifreeze used in the precipitation gages. A net of galvanized, 3/16 inch cable covers the bladders and is bolted down around the edges to prevent large animals from damaging bending or puncturing the metal while attracted to the antifreeze contained within. Plumbing from the pillow connects to a Sensotec pressure transducer that measures pressure exerted on the antifreeze solution by the snowpack; this measurement is then converted to an equivalent water depth (SWE) for that snowpack.

KREW decided to forego fencing the meteorological stations. This decision was made after discussions with Sierra Snow Lab personnel (Osterhuber personal communication, 2001). There was concern that a fence would alter the snow deposition pattern and also accelerate melt due to re-radiation: this would affect the snow pillow measurement. The Sierra National Forest has no requirement that the equipment be fenced (Porter personal communication, 2002).

The set of four metal pillows were placed at each site in fall 2004 and replaced existing rubber (hypalon) pillows that had been in place since 2002. The rubber pillow design proved problematic during their two-year tenure, developing leaks in the plumbing and sustaining punctures and tears from large animals in pursuit of antifreeze.

The choice of instruments was made to provide components capable of surviving the extreme climatic conditions that are possible at the field locations. Rugged sensors were selected to handle summer and winter temperature extremes, as well as wind, ice, and snow. The final sensor choices are listed in Table 5.2-2.

Table 5.2-2—*KREW meteorology sensors information.*

Component	Manufacturer	Model	Height[a]
Datalogger	Campbell Scientific, Inc.®	CR10X	3 m (10 ft)
Temperature / relative humidity probe	Vaisala, Inc.®	HMP45C	4 m (13 ft)
Pyranometer	Kipp & Zonen B.V. ®	CM3	5 m (16 ft)
Anemometer	Met One, Inc.®	013A	7 m (23 ft)
Wind vane	Met One, Inc.®	023A	7 m (23 ft)
Snow depth sensor	Judd ®Communications	Depth Sensor	5 m (16 ft)
Precipitation gage	Belfort Instrument Company®	76 cm (30 in) precipitation gage	4 m (13 ft)
	Novalynx Corporation®	260-952 Alter-style wind screen	4 m (13 ft)
	Tedea-Huntleigh, Inc. ®	Model 1042 loadcell	Not applicable
Snow pillow	Mendenhall Manufacturing®	4, 1.2 X 1.5 m (4X5 ft) stainless steel bladders, connected by plumbing	Ground level
	Sensotec, Inc. ®	254 and 381 cm (100 and 150 in) pressure transducer	Slightly below ground

[a] indicates height above tower base

Full documentation for each component of the meteorological stations is provided in the Resource Binder for the KREW Permanent Weather Stations (Anderson, 2003). Individual sensors were sited according to recommendations given by the manufacturer; however, due to the sometimes deep Sierra Nevadan snow pack some sensors were positioned higher to keep them above the snow during the winter. Table 5.2-2 provides the height of each instrument. Changing sensor heights to accommodate for snow is an acceptable practice (USEPA, 1987).

Historical snow water equivalence (SWE) data (CDEC, 2002) were used to estimate the deepest snow packs KREW could expect on the ground at any one time. The following formula was used to calculate snow depth:

Snow Depth = SWE / Density of Snow Pack.

A density of 0.40 m/m (water/snow)was assumed. During the biggest years the weight of overburden may compact the snow pack, increasing the density and decreasing the overall depth.

The results of this calculation provided the following information. Between elevations of 1,700-2,000 m (5577-6562 ft), representative of the Providence Site, the deepest recorded snow pack was estimated at 3.05 m (10 ft). At 2,150 m (7054 ft), the lower Bull elevation, the largest snow pack could have been 3.05-4.57m (10-15 ft). At 2,500 m (8200 ft), Upper Bull, the maximum snow depth was between 4.11-5.70 m (13.5-19 ft). All these values are estimates of the snow pack present on the ground at some time in the past; they are not annual snowfall totals. Although the numbers are high, it is important to remember that these numbers represent a handful of years with extremely deep snow packs, and in no way do they represent what is most likely during an average year.

To make the overall design more simple and consistent, it was decided to keep similar sensors the same distance off the ground at each site. Furthermore, the minimum height was chosen to be 4 m (13 ft). Based on SWE data the Providence sensors will likely be further off the snow surface during the winter than in Bull, however, it will allow the sensors at all locations to be at the same height above the tower base when snow is absent.

5.2.3 Meteorology Measurements

Most often measurements are recorded on a 15-minute interval with maximums and minimums being recorded on a daily basis. Table 5.2-3 shows a summary of the frequency at which each variable is recorded, as well as the units for each variable and whether the value is a sample or an average. A sample is a one-time reading. A 15-minute average is the mean of 360 samples taken on 2.5-second intervals since “substantial evidence and experience suggest that 360 data values, evenly spaced during the sampling interval will produce estimates of the standard deviation to within 5-10%. Estimates of the mean should be based on at least 60 samples to obtain a similar level of accuracy. This is regardless of the sampling interval. Therefore for an hourly standard deviation, the sampling needs to be at least every 10 seconds. If the data are first combined into 15-minute averages then the data must be sampled every 2.5 seconds to provide 360 samples during the 15-minute period, even if the four 15-minute values are later combined into an hourly value” (USEPA, 1987). Precipitation and Snow Water Equivalence are the exception to this rule. Throughout most of water year 2003 these variables were recorded as a one-minute average at the end of each 15-minute interval. This was done to more precisely tie

the timing of stream discharge hydrographs to precipitation during storm events. Reviewers of the study plan recommended sampling precipitation each minute in order to allow calculating storm intensity (Osterhuber, personal communication).

Table 5.2-3—*KREW sampling frequency and units of meteorology variables.*

Variable	Frequency	Units
Temperature	15 minute average 24 hour maximum 24 hour minimum	°C
Relative humidity	15 minute sample 24 hour maximum 24 hour minimum	%
Solar radiation	15 minute average flux 24 hour totalized flux density	W/m^2 MJ/m^2
Wind speed	15 minute sample Daily maximum 10 second wind gust	m/s
Wind direction	15 minute sample Direction of daily maximum 10 second gust	degrees (0-360)
Wind run	24 hour total	km
Snow depth	15 minute sample	cm
Precipitation	1 minute average every 15 minutes (WY 2003) 1 minute sample (WY 2004 and later) Daily change in precipitation	cm
Snow water equivalence	15-minute sample	cm

5.3 Stream Channel Characteristics and Geomorphology

KREW staff designed a channel morphology survey using the methodology of Harrelson (1994), the Stream Condition Inventory (USDA, 1998), and the Herbst Invertebrate physical habitat survey. The first category is baseline data, these measurements will be taken once before the treatments and once after the treatments. The second category includes detailed monitoring of monumented cross-sections and the Herbst invertebrate physical habitat survey. The measured attributes are outlined in tables 5.3-1 and 5.3-2. KREW uses established protocols to make the results comparable with other projects, however in some instances the established protocols may be modified to accommodate the nature of the KREW headwater streams.

5.3.1 Longitudinal Profile Data

The longitudinal profile of the thalweg, water surface, and bankfull indicators, as described by Harrelson et al. (1994), will be performed in each watershed, starting just upstream of the lowest flume and ending at the headwaters. This profile will be done with surveying equipment (a total station). The thalweg will be mapped accurately enough to locate pools, riffles, channel slope and sinuosity.

5.3.2 Cross-section and Monitoring Data

Monitoring of monumented cross-sections will occur using a modified field intensive SCI protocol. Three permanent cross-sections were identified in all of the channels except for B201 which has two and T003 which has five (varies by stream length and availability of adequate locations). These monumented cross-sections consist of rebar placed perpendicular to the stream flow, above flood prone stage height. Locations were surveyed into the longitudinal profile using a total station. At each monumented cross-section a modified SCI protocol was followed to define the channel morphology. The data collected at the monumented cross-section includes 5 upstream and 5 downstream cross-section locations where bankfull width, flood prone width, average depth, bank stability, bank angle and percent sunlight is measured Large woody debris was surveyed based on size, distribution and function for the survey segment from flume to headwaters. Intensive pool measurements were conducted on 6-10 pools per channel. A detailed large woody debris count is conducted for the entire flume to headwaters segment. The large woody debris survey classifies wood size, distribution, affect on flow and whether pieces occur within aggregates or as a single piece.

Table 5.3-1—*Geomorphology measurements.*

Location of **measurement**	**Attribute**
Survey Segment (flume to headwater)	Longitudinal profile Water surface slope Channel sinuosity LWD count Water temperature Cross-sections (2-5 per stream, monumented)
Monumented cross-section	Bankfull width and depth Floodplain width Entrenchment ratio Width to depth ratio Percent surface fines in channel material (v-star) Bank stability Bank angle Percent sunlight Wetted width

5.3.3 Herbst Physical Habitat Survey

The Herbst invertebrate physical habitat reaches, which were selected in June 2002, are usually upstream of the flume or weir and are included in the longitudinal profile, some SCI cross-sections may be located within the invertebrate reaches. Because of the nature of small headwater streams, KREW uses a shortened sampling reach (100m) and fewer transects. Physical habitat is measured over the length of each reach using transects spaced at 10 m (33 ft) intervals. Water depth, substrate type, and current velocity are measured at five equidistant points on each transect along with stream width, bank structure (cover/substrate type and stability rating), riparian canopy cover, and bank angle. Bank cover between water level and bankfull channel level was rated as either vegetated or armored (rock or log), and as stable or eroded (evidence of collapse or scour scars). Bank angles are scored as shallow, moderate, or undercut (<30°, 30-90°, and >90°, respectively), and riparian cover is estimated from vegetation reflected on a grid in a concave mirror densiometer (sum of grid points for measurements taken at each stream edge and at mid-stream facing up- and downstream). The type and amount of riparian vegetation along the reach is also estimated by qualitative visual evaluation. The embeddedness of cobble size substrate is estimated as the volume of the rock buried by silt or fine sand for 20 cobbles (encountered during transect surveys or supplemented with randomly selected cobbles). Water velocity and basic water chemistry measurements collected include; conductivity, pH, temperature, and turbidity. Documentation also includes photographs taken at mid-stream looking upstream at 0, 50 m, and 100 m. Slope over the reach is measured with a clinometer, and sinuosity is estimated from the shortest linear distance between the bottom and top of the reach (or on aerial photographs with 500-1000 m (1640-3280 ft) of stream length centered on the study reach when stream length is greater than 40 widths). For the Herbst physical habitat data sheets and the associated code form see appendix section 18.5. Table 5.3-2 summarizes the measurements taken in the Herbst protocol.

Table 5.3-2—*Herbst physical habitat survey used by KREW.*

Data type	Measurement
Reach data (100 m reach)	Habitat type (pool/riffle/other sequence) Stream temperature pH Conductivity Turbidity (NTU) Flume size and stage Slope (from 0-25m, 25-50m, 50-75m, 75-100m) Photos (upstream and downstream at 0, 25, 50, 75, 100m) Riparian vegetation cover
Location data (downstream end of reach)	GPS UTM Elevation
Transect data (10 per reach 10 m apart)	Stream width (wetted width) Bank cover (right bank, left bank) Bank angle (right bank, left bank) Vegetative shading (right bank, left bank, upstream, downstream) Stream depth (5 per transect) Stream velocity (5 per transect) Stream substrate class (5 per transect) Cobble embeddedness (20 cobbles total)

5.4 Sediment

KREW has several measurements that contribute to an estimate of total watershed sediment yield. Sediment catchment basins and turbidity measurements/automated samplers collect in-stream sediment transport data. Hillslope erosion measurements are collected using sediment fences which are used to estimate hillslope and swale erosion. Headcut sediment loss is measured using bank pins and surveying of the location pre-treatment and post-treatment with a total station. Pre-treatment information will be used to quantify undisturbed conditions and post-treatment data will quantify sediment loss related to treatments.

5.4.1 Sediment Basin Design

Sediment basins are a low-tech way of measuring sediment produced in a watershed. They are most effective at capturing sand and larger size particles. Although there is a lot of physical work in emptying them, there is no problem with instrument malfunction. The biggest drawback is that on most watersheds the majority of matter moves in the large storms. The 20-year storm may over fill our sediment basins.

We have built well-designed sediment basins in eight streams with 12 to 40 m^3 (423 to 1412 ft^3) of storage space each. In P301, P304, D102, B201, B203 and B204 natural deposition areas that existed directly below the large flume sites were transformed into sediment ponds (Figure 5.4). Watershed T003 has a permanent concrete catchment basin that was constructed in 1939 and has a 200+ m^3 storage capacity. The natural deposition area was then dug out.

KREW staff placed logs which were drilled and held in place with rebar at the outlet and along the right and left banks. The sediment basins were lined with 20/1000-inch thick rubber pond liner.

5.4.1.1 Measurements of Sediment in Ponds

KREW is interested in estimating the following: the dry mass of the annual sediment load for each basin, the relative percentage of organic versus inorganic material in that load, and the class size distribution within the inorganic fraction. To do this a field collection is performed and laboratory analysis are conducted on a sub-sample. The field collection serves to measure the wet volume and mass of the entire annual sediment load, as well as to collect a proportional sub-sample for laboratory analysis. The laboratory analysis of the sub-sample is used to extrapolate the dry mass, as well as calculate the percent organic versus inorganic and the class size distribution within the inorganic fraction.

5.4.1.2 Field Data Collection

The field collection is done each September, prior to October 1st, the start of the new water year. Stream flow is re-routed under the pond liner through the flexible, sewer-pipe diversion. The water remaining in the basin is emptied using siphons and/or gasoline powered pumps. Intakes are positioned to prevent sediment from being drawn out of the basin. Once the water level reaches the top of the sediment material all suctioning and pumping is stopped. The basin's sediment load is still wet at this point. Ideally the basin should be allowed to sit while the excess water evaporates; however, the diversion is not perfect and water does seep into the basin, preventing any real drying. Wet sediment is shoveled out of the basin into 5-gallon buckets and is weighed. Larger wood pieces are set aside to dry and are weighed after they have dried. Even after prolonged drying, experience indicates that a substantial volume of the material in the basin is composed of water. To get around this problem KREW collects a proportional sub-sample that is representative of the basin's sediment load and used after field collection for a laboratory analysis that is then applied to the entire basin to extrapolate an estimate of the annual values. The weight of the sub-sample is measured to the nearest kilogram using a spring scale. The sub-sample is placed in a separate container, labeled, and set aside for later laboratory analysis. The remainder of the material in the basin is collected using shovels and push brooms into buckets with known weights. The wet weight and volume of each bucket is recorded and then the material is piled in a location away from the stream and downstream of the basin.

5.4.1.3 Laboratory Data Analysis

The sediment samples collected from each of the basins is divided and mixed until an approximately 2 kg sample is created. This sample is dried and weighed to determine its mass.

The difference between the weights of the sample while wet and the sample once it is dried will give the percentage of water found in the sample.

KREW staff then manually removes the coarse organic debris by adding water and quickly removing the organics that float to the top. The sample is dried and re-weighed resulting in the weight of coarse organics. The inorganic sediment is sieved to determine weights and percentages of each particle size. The particle size distribution ranges from 2.0mm to 63 microns. Additionally fine organics are combusted at 500°C for 24 hours, This final fine organic percent is applied to the sample dry mass. The sample results are applied to the basin data as a whole. KREW data output includes the total dry mineral mass that was deposited in the basin each water year and the mass of organics.

5.4.2 Headcuts

A headcut is a vertical or near vertical drop or discontinuity on the bed of a stream channel, rill or gully. Headcuts move upstream which affects the landscape by contributing to soil erosion (Hanson, Robinson, and Cook, 1996). Measuring headcuts is a surveying exercise where permanent control points are crucial. A set of stakes will be pounded into the stream every 0.3 m (1 ft). All stakes will be tied back to permanent metal tags on trees so that if the stake disappears they can be reset. As these stakes “fall off” the edge of the headcut, lateral movement will be tracked. Depth can be measured below the surrounding ground. Width can be measured where every stake used to exist and every 0.3 m (1 ft) downstream of where the headcut was when monitoring was started to where there is no sign of a headcut. A multiple lobbed headcut would need a line of stakes for each lob and a more complex width measuring procedure. This is meant to be a very rough sketch of methods.

KREW staff believes that soil loss from headcuts will need to be measured to +/- 0.5 m^3 (18 ft^3) because the volume of sediment that we are collecting in our sediment basins is small. It will be a challenge to measure headcuts with sufficient precision.

5.4.3 Sediment Fences for Upland Erosion

KREW would like to quantify erosion of upland areas of the watersheds to augment the annual sediment loading estimated by the sediment ponds. We have been discussing options with Lee McDonald at Colorado State University and Brian Stabb, hydrologist for the Pacific Southwest Region, who are performing this type of monitoring in other Sierra Nevada locations. Upland erosion measurements would vary from sediment ponds and turbidity measurements as sediment fences only collect sediment from a small, targeted portion of the watershed. Such measurements may help us evaluate localized effects of pile burning, skid trails, existing roads, and landings.

5.5 Turbidity and Suspended Sediment

KREW has established continuous turbidity monitoring on each stream within the study. To establish a correlation between turbidity and suspended sediment a large number of SSC samples must be collected for each watershed. A majority of the sediment transported on the KREW streams occurs during a few large runoff events under winter conditions. It will be nearly impossible to have staff in the field for these events at each watershed in order to collect the grab samples necessary to create the turbidity/SSC relationship. The automated samplers (ISCO 6712) located at each flume site must be used for the sampling requirements. The high cost of outsourcing the analysis of sediment samples will require KREW to establish its own SSC processing protocols.

5.5.1 Continuous Turbidity Monitoring

There are a number of problems associated with continuous turbidity monitoring. Algal growth and fouling of the probe's optical face is common. Instrument deployment is of critical importance as probes may become blocked with debris or buried under sediment following storm events. In addition, KREW faces the difficulties associated with snow and ice during the winter. Encasement in ice may damage submerged probes or any moving parts and collapsing snow bridges and banks are common enough that many turbidity spikes may not be related to sediment at all.

A number of factors were used to select the probe best for KREW conditions. The instrument must have a wiper blade that will clean the optical face on regular basis to prevent fouling. Probes must also be small enough for effective deployment in KREW streams. In addition, the amount of stream volume required to accurately determine turbidity must also be small. Finally, in order to log the turbidity data using the existing ISCO 6712 automated samplers the probes must be SDI-12 compatible. This eliminates the need for any additional data logger equipment or software. Also, by running the turbidity probes in conjunction with the ISCO samplers it becomes much easier to collect suspended sediment samples based on turbidity. Of the turbidity sensors on the market, the Forest Technology System DTS-12 probe was the best fit for these specifications. It is approximately 1 foot in length and only requires two inches beyond the optical face of the probe to obtain a turbidity measurement. It also has the wiper and SDI-12 compatibility required by KREW.

Probes were deployed to obtain the best possible measurements of turbidity. Each probe was housed in PVC case which had been cemented into concrete blocks. The blocks provide stability and protection from debris during peak flow events, yet still allow the probes to be removed for maintenance. In order to protect the wiper blades from ice probes were placed in deeper sections of the stream. Ideally each probe is 4 to 5 inches from the surface, yet still at least 3 inches off the bottom to keep sediment deposition and bed load transport from affecting

turbidity measurements. The blocks are placed near the stream bank with the probes extending horizontally and perpendicular to the flow. The SDI cable for the sensors is housed in PVC and buried to the connection with the ISCO sampler in the instrument shed. Turbidity and temperature are recorded using the ISCO 6712 data logger on 15 minute intervals. This interval matches the interval used by the ISCO's for recording stream gage height. The data are transmitted to Fresno with stream gage height via the radio telemetry systems installed at each site.

5.5.2 Suspended Sediment Sampling

In order to establish a relationship between turbidity and suspended sediment it will be necessary to collect a large number of SSC samples will be required at different values for turbidity. Higher turbidity values in the KREW watersheds are typically only found during the larger rain events. For this reason, a majority of SSC sampling must be storm based. The travel time and hazards associated with storm sampling will make field visits for grab samples extremely difficult. In addition, samples will be required from all ten gaging sites during storms. KREW does not have the personnel or resources to make this feasible. SSC grab samples will be collected when possible, however the bulk of the SSC sampling will have to come from the ISCO portable samplers.

The ISCO's can be programmed to sample based on turbidity as well as discharge. Thus, at each instrument shed, at least 4 bottles have been allocated for SSC sampling. When the turbidity value rises to a certain level, it will trigger the ISCO to begin sampling over a given time interval. This is typically one sample every 15 to 30 minutes. Turbidity peaks occur rapidly and will tend to reach a maximum value well before the discharge peaks. In larger storms, it may be possible to use ISCO bottles set aside for water chemistry sampling in order to obtain additional SSC samples.

The SSC samples will be processed by KREW in the Fresno lab. This is accomplished following a procedure outlined by PSW Arcata and their extensive SSC sampling program. It involves filtering, drying, and weighing the samples to determine the amount of suspended sediment. With the lab setup, KREW is capable of processing approximately 30 SSC samples per day. Ideally, in a typical storm KREW would collect 40-60 samples.

Suspended sediment results will be used to develop a turbidity/SSC rating curve for each site. The curve can be used to convert the continuous turbidity data for each watershed into suspended sediment. It is not yet known whether the rating curve can be used over the duration of the project or if it will be necessary to develop a new curve each year. Some studies have found that the relationship between SSC and turbidity is different between the rising and falling limbs of storm hydrographs. If KREW is capable to go into this much detail to determine the SSC relationship remains to be determined.

5.6 Soil Characterization

Both physical and chemical characteristics of the watersheds' soils are being characterized and those methods are described in this section. Methods for soil water chemistry are described in Sections 5.6.1.2 and 5.6.1.3. KREW staff (including Dale Johnson and Brent Roath) met with Jim Baldwin, PSW statistician, and designed the layout for the watershed grid for soil characterization and water chemistry sampling. The grid also provides the framework for sample locations for upland vegetation and fuels loading measurements. Soil maps for the experimental watersheds were reviewed. In general, the dominant soil type by watershed accounts for 50% or more of the area (Table 4.1-1). The Bull Site is dominated by Cagwin soil. Three of the Providence Site watersheds are dominated by Shaver soil and the other is dominated by Gerle-Cagwin soil. It was decided that a uniform grid rather than any type of stratification would be the best approach for sample location. Several uniform grids with different spacing (100 m, 150 m, and 200 m) were considered. The 150 m (492 ft) grid was selected to provide an adequate sample size for most watersheds. The grid spacing was densified for the two small watersheds (P304 and B201) to provide an adequate sample size (Table 5.6-1). After the first year of data is collected, the variability in chemistry measurements will be evaluated and a decision will be made on the need for retaining this sample intensity or possibly reducing it and in what manner.

5.6.1 Watershed Grid

The watershed grid was established using a compass, a Trimble® Pro XRS Geographic Positioning System (GPS), and laser measurement instruments. The points are within 1-3 m (3.3-10 ft) of the desired location depending on canopy cover and terrain which both affect the performance of the GPS. The grid for the Providence Site was installed in 2002 (Figure 5.6-1), and the grid for the Bull Site was installed in 2003 (Figure 5.6-2). Each point is permanently marked by a 0.6 m (2 ft) red plastic stake with an attached stainless steel tag embossed with the grid and watershed codes. A second coded tag is placed on an earth staple and pounded into the ground at the base of the red stake. Locations are also flagged with lime green flagging.

After the full grid was established, a set of characterization data was recorded (see appendix 18.6). When the grid points are revisited each year, visual estimate of vegetation type and cover is recorded and any obvious disturbance is noted and additional photos taken.

Table 5.6-1—*Watershed grid point density and characteristics.*

Watershed code	Number of grid points	Grid spacing	Number of points under forest canopy	Number of points in openings
P301	44	150 m (492 ft)	35	9
P303	60	150 m	47	13
P304	39	150 m in east-west direction 75 m (246 ft) in north-south direction	31	8
D102	54	150 m	47	7
B201	45	150 m in east-west direction 75 m in north-south direction	12	12
B203	63	150 m	37	26
B204	72	150 m	32	40
TK3	100	150 m	70	30

5.6.2 Soil Sampling

Soil sampling begins in 2003 for the Providence site and will continue through the pre-treatment phase of the project. We plan to sample 40 grid points in 2003, analyze these data, and then make a final determination on how many points will have soil samples and how they will be distributed across the watersheds. Dale Johnson is the lead scientist on the soil characterization design, and Brent Roath is the lead person doing the field and laboratory work on soils. We plan to sample once during the pretreatment period and once immediately after the treatments.

The soil sampling design has the following purposes.

1. Describe the soil profiles for the major soils within the study area.
2. Determine the rock content to enable an accurate determination of bulk density and to permit the calculation of organic matter and nutrient levels expressed in concentration per unit area (kg/hectare, lb/acre).
3. Collect samples for organic matter and nutrient analysis.
4. Characterize plots for large woody debris.
5. Characterize plots for live vegetation density.
6. Collect satellite samples from the main sample points to measure variability of the O layer and mineral soil.

At a selected grid point, the soil sample is taken 10 m (32.8 ft) north of the plot center and monumented with a wire survey flag. A soil pit is dug to 1-m depth (3.3 ft) or bedrock contact. A full soil profile description is completed and includes horizon depths, designations, soil texture, color, structure, consistence, etc. From each horizon a soil core is collected using a soil core sampler; this core will be used to determine bulk density (exclusive of large rock fragments found during coarse sieving). From each horizon about 0.5 L of soil is collected for nutrient analysis (collect across the thickness of each horizon and mix to form a composite sample). From each horizon a small portion of mineral soil will be sieved and taken to the laboratory to measure soil moisture content.

The O soil layer is sampled by pounding a PVC sampling ring through the O layer into the top of the mineral soil. The soil is removed and the Oi, Oe, and Oa layers are separately bagged. The Oi layer is made up of relatively fresh leaves and needles and does not include bark or other woody materials. Other woody materials such as bark, cones, branches, and roots are bagged separately. The Oe layer includes organic material that is partially broken down, but still made up of recognizable materials such as needles or leaves. The Oa layer is composed of very dark humic material that is amorphous and not recognizable. Sometimes mineral soil is mixed into the Oa layer, and ashing would need to be done to determine what portion was actually organic and what was mineral.

Mineral soil is removed from each horizon separately and passed through a coarse sieve to separate larger gravels and rock fragments from the finer mineral soil. The total of rock fragments that do not pass both the coarse sieve and a 2 mm (0.06 in) sieve make up the total rock fragments greater than 2 mm. The rock fragment fraction that does not pass through the coarse sieve and the material passing through the sieve are placed in separate buckets and weighed using a field spring scales. This procedure along with the collection of a soil core permits the accounting for all coarse fragments and correction of soil bulk density. The bulk density is needed to make accurate determinations of nutrient content (kg/ha, lb/ac). After weighing, a few rock fragments are kept and bagged to determine their density. Their volume is determined using a water displacement method, and they are dried and weighed.

Large woody debris is measured within a 0.1-ha (0.25 ac) circular plot (17.8 m radius, 58.4 ft) around the soil sample plot center. Within this area all woody debris larger than 2.5 cm (1 in) is measured using a caliper to measure the diameter of both ends and the length. The dbh (diameter breast height) is measured for all live trees and shrubs. If stumps occur, then the dbh of the stump is measured at 10-cm (3.9 in) height on the uphill side of the stump.

Six satellite samples of the O layers and mineral soil samples by horizon will be collected in an array near the soil sample site. The six sites are determined by random coordinate selection and are taken 10 m (32.8 ft) from the main soil sample point. A soil bucket auger is used to collect samples below the O layer. A sample of each horizon is collected for possible analysis of total carbon, nitrogen, and other nutrients (extractable P, cation exchange capacity, exchangeable cations). ***Available funding will be the limiting factor for this work, what should have highest priority for being measured?*

5.6.3 Laboratory Analyses of Soils and O Horizons

If funding is available, O horizon samples will be analyzed for N (Perkin-Elmer CHN Analyzer), P, K, Ca, Mg, and S (dry-ashing at 550°C for 4 hours, dissolution in 5% (v/v) HNO_3, and analysis by ICP). Soils will be analyzed for total C and N on the Perkin-Elmer, NH_4^+, and NO_3^- (2 M NH_4Cl), exchangeable Ca^{2+}, Mg^{2+}, K^+, and Al^{3+} (1 M NH_4Cl); extractable P (both bicarbonate and weak

Bray; Olsen and Sommers, 1982), and extractable SO_4^{2-} (0.016 M NaH_2PO_4; Johnson and Henderson 1979).

5.7 Water Chemistry

Within a watershed the chemical composition of stream water serves as an indicator of the condition of the watershed. Our goal is to measure water chemistry in several parts of the hydrologic cycle including incoming precipitation, shallow soil water, and stream water. Currently KREW is measuring several anions and cations (Table 5.7-1). In general, water chemistry measurements are taken every two weeks. During or directly after a storm event sampling is more frequent. Resin lysimeters measure annual flux of water and are collected once a year. All water samples are collected between 8:00a.m. and 5:00 p.m. They are placed in the freezer at the end of the field day. Samples are shipped by overnight FedEx service approximately once a month. There is usually ice in the containers when they arrive at the PSW Riverside chemistry laboratory. The receiving chemist at Riverside is notified of a shipment prior to the day FedEx picks it up in Fresno. If the samples do not contain ice or too much time has elapsed since removal from the freezer in Fresno, they are eliminated from the sample batch. This precaution is taken because certain chemicals will deteriorate after over a short time period with exposure to warm temperatures. The bottles that are sent to the lab are labeled with an assigned Riverside lab ID number. All other sample information including the site ID, time, date, and initials of field technician are recorded in the field notebook and transferred to the project database the next day.

Table 5.7-1—*Chemical parameters being measured in water or water fluxes.*

Chemical parameter	**Stream water**	**Soil water by Prenart vacuum lysimeters**	**Soil water and precipitation by resin lysimeters**	**Snowmelt collectors**
Anions				
Phosphate PO_4^{3-}	X	X	X	X
Nitrate NO_3^-	X	X		X
Sulfate SO_4^{2-}	X	X		X
Chloride Cl^-	X	X		X
Cations				
Ammonium NH_4^+	X	X	X	X
Calcium Ca^{2+}	X	X		X
Magnesium Mg^{2+}	X	X		X
Potassium K^+	X	X		X
Sodium Na^+	X	X		X
Electrical conductivity EC	X	X		X
pH	X	X		X
Alkalinity	X	X		X

Alkalinity determines buffering capacity against pH change and biological effects. The solubility of substances harmful or beneficial to biota is directly affected by pH. A pH value of less than 5 can be harmful to some aquatic organisms. Calcium is the primary base cation accounting

for the majority of water alkalinity and hardness. Magnesium is the second most important cation accounting for the remainder of water hardness. Potassium and sodium are the two most abundant members of the alkali-metals group measured in natural water. Sources of these elements include igneous and sedimentary rocks. The element chlorine is the most important and widely distributed of the halogen group of elements in natural water. Its dominant form in water is Cl^-, which is usually found at low concentrations relative to other anions such as SO_4^{2-} and HCO_3^-. Phosphorus is a nutrient that usually limits aquatic production in the form of phosphate ion. Total phosphorus includes all soluble and particulate forms of inorganic and organic phosphorus. Nitrogen is a nutrient that limits terrestrial plant production and can limit aquatic production in the form of ammonium or nitrate ion. Nitrate (NO_3^-) is the predominant form of dissolved nitrogen in oxygenated waters. Other chemistry measurements include electrical conductivity (EC), which is used to estimate total dissolved solids in stream water and to double-check the results of the cation tests, and pH – an indicator of the hydrogen ion activity in the soil water.

5.7.1 Soil Water

KREW currently uses two types of lysimeters to characterize the nutrient fluxes and chemistry of shallow soil water. Soil resin lysimeters are placed on a uniform grid spaced at a depth of 13 cm (5 in) to measure the annual flux of nutrients through the forest litter and overlying soil layers. Four Prenart vacuum lysimeters provide a continuous measurement of soil water chemistry at 13cm and 26cm during the period of the year when the shallow soil is wetted at or below 26 cm (10 in). The vacuum lysimeter data provides information on the variability of chemistry fluxes during the wet season. These two soil water measurement devices are considered practical and complimentary for areas the size of the experimental watersheds.

5.7.1.1 Site Selection for Soil Vacuum Lysimeters

The four watersheds at the Providence Site each contain a Prenart vacuum lysimeter operating since October 1, 2003 (Figure 4.1-2). Snowmelt collectors are co-located at these sites (see Section 5.7.2). The locations range from 1800 m (5900 ft) to 1900 m (6234 ft) in elevation and have a western aspect (Table 5.7.2). We piloted a Prenart at watershed P303 for two years to ensure it could be operated during our winter snow conditions. We do not intend to install Prenart systems at the Bull Site because of winter accessibility and the high cost of running and maintaining these instruments. The Providence Site should provide adequate data on the wet season variability of shallow soil water fluxes. The following criteria were used in the selection of the location for the Prenart vacuum lysimeters:

- The area should be representative of the watershed as a whole.
- The area has the same physical setting as sites in other watersheds (vegetation, slope, aspect, and soil profile should be consistent or similar across all sites chosen).

- The area will burn well if prescribed fire is applied at this site as an underburn.
- The area has little or no obvious impact from historical activities (livestock grazing, timber harvest, roads, slope erosion, etc.).

The primary consideration for the Prenart vacuum lysimeter sites was that all four sites be on the same soil type. Three sites are placed on true Shaver series soils while the Duff 102 location is on a very similar soil. Brent Roath, a Sierra National Forest soil scientist, verified these soil classifications in the field. All four sites have sandy loam for the first meter of depth. The Duff site has a significant percentage of cobbles, but this is not expected to alter the soil water chemistry. We avoided choosing locations with remnants of old skid trails because the soil horizons could be mixed up in such areas.

Coniferous and deciduous trees alter soil chemistry differently so we strove for sites predominated by white fir and pine with as little black oak as possible. We selected areas that were fairly homogeneous for 25 m by 25 m (82 ft by 82 ft). The homogeneity was to try to insure that all 12 lysimeter tips were exposed to similar conditions. The sheds were placed at a downslope position in the middle of this selected area. All sites have slopes between 15-35%; this is typical for the area, and we thought it would help to carry the fire. We sought to have the elevation and aspect similar between sites so the snow pack would melt at similar times.

The selected sites have enough standing timber that a mechanical thinning operation could take approximately half the volume and still leave enough trees to fully utilize the site. Basal area was estimated at 300-400 ft^2 per acre. All four sites have white fir in the 0.25-0.8 m (0.8-2.6 ft) size class accounting for at least half of the basal area. Some sites had a few large trees.

Table 5.7-2—*Location of vacuum lysimeters and co-located snowmelt collectors.*

Watershed code	UTM 11s Easting	UTM Northing	Elevation (m, ft)	Aspect
Providence 301	304,294	4,104,127	1914, 6280	Southwest
Providence 303	304,964	4,102,920	1823, 5981	West
Providence 304	305,320	4,102,500	1887, 6190	West
Duff 102	305,292	4,101,965	1890, 6200	West

We also sought out areas with enough ground fuel that we believed it would carry a fire. Ground fuels were typically from 2.5 to 15 cm (1 to 6 in) in diameter. If these sites are burned in the fall, flame lengths might be 0.3 to 0.9 m (1 to 3 ft). A High Sierra Ranger District staff member, Keith Ballard, visited each site with Sean Eagan to confirm location selection for the ability to support a thinning or burning treatment.

5.7.1.2 Prenart Vacuum Lysimeters

A Prenart soil water sampler and pump system is used to extract water from the soil by creating a vacuum greater than the soil suction holding the water in the capillary spaces. The vacuum is set

at approximately -0.25 to –0.5 bars. The tips of the suction system are placed at depths of 13 cm and 26 cm below the duff layer. At each watershed location six tips collect from the 13 cm depth and six tips collect from the 26 cm depth. The tips are placed on both the left and right sides of the shed containing the vacuum pump and collection bottles. These lysimeters are powered by a solar panel placed in a nearby tree. Specific details of the location layout are provided in Figure 5.7-1 and Table 5.7-3.

Table 5.7-3—*Layout for Prenart vacuum lysimeter collectors. Six tips are placed at each soil depth. Snowmelt collectors are placed two meters downslope of each tip location.*

Tip depth	**6 m (20 ft) left of shed**	**4 m (13 ft) left of shed**	**2 m (7 ft) left of shed**	**Shed housing Prenart Pump**	**2 m (7 ft) right of shed**	**4 m (13 ft) right of shed**	**6 m (20 ft) right of shed**
13 cm (5 in)	Bottle 5	Bottle 3	Bottle 1		Bottle 7	Bottle 9	Bottle 11
26 cm (10 in)	Bottle 6	Bottle 4	Bottle 2		Bottle 8	Bottle 10	Bottle 12

At approximately two-week intervals, the bottles are emptied. The volume of water found in each bottle is recorded and a compiled sample from each depth is retrieved in a 125mL Nalgene bottle for chemical analysis. The snowmelt water is collected at this time as well (see Section 5.7.2).

In general, the chemistry derived from the soil water and snowmelt is collected and analyzed every two weeks, beginning when significant precipitation occurs at the start of the wet season. This typically occurs in late October or early November. If there is little or no precipitation, KREW reduces the amount of visits to the sites until more rain or snow occurs. When the soils begin to dry up in the late spring (May or June), we no longer visit the soil study locations because the vacuum system will not extract anything of significance. Typically no significant precipitation events occur during the summer and early fall that would saturate the soil and allow sample collection.

5.7.1.3 Soil Resin Lysimeters

A single soil resin lysimeter is placed as close as possible to the six Prenart tip locations. Two soil resin lysimeters are placed at each watershed grid point (see Section 5.6). At each grid point, a north and south lysimeter are placed in the soil at 13 cm (5 in) depth below the O horizon. The string that is attached to the lysimeter is brought up above ground and tied to a wooden dowel that is pounded into the earth near the lysimeter. The distance and direction from the grid marker is recorded, along with the O soil horizon thickness for each resin hole. If a lysimeter cannot be placed at exactly north and south of the grid point marker (because of rock, tree, water, road, etc.), a protocol exists for alternate placement (see appendix 18.7). If the resin cannot be placed,

this grid point is removed from the sampling framework. The resins are installed during the late summer and early fall and removed during the early summer of the following year; soil and throughfall resins are placed in the field at the same time.

The soil resin lysimeters are built according to a design published by Susfolk and Johnson (2002) and illustrated in Figure 5.7-1b. To create the bottom of the lysimeter, an 11 cm (4 in) square of Nitex® brand nylon netting is placed over a 1 cm (0.4 in) long piece of PVC pipe that is inserted into a 5.5 cm (2 in) long PVC coupling piece so that the ends are flush. The 1 cm (0.4 in) insert is filled with washed silica sand and covered by cheesecloth that is secured with a rubber band. Ion exchange resin (22 ml of Rexyn® brand) is added to the other end of the coupling. An 11 cm (4 in) square of Nitex brand netting is placed over the PVC coupling, and a 3 cm (1.2 in) PVC tube is inserted until it is fully seated in the PVC coupling. The upper 3 cm (1.2 in) insert is filled with washed silica sand and covered with plastic film secured with a rubber band. Soil resin lysimeters are stored in a sealed plastic bag and refrigerated until placement in the field.

At the time of placement the lysimeter is coded with the grid location and dated (see appendix 18.8 for field protocol). The plastic film is removed before installing. When the lysimeter is collected it is placed by itself in a labeled plastic bag and stored at room temperature until it is shipped to the PSW Riverside chemistry laboratory for analysis. At the laboratory the resin is removed from the lysimeter by cutting the netting and pouring it into a beaker. The resin is put into a 250-ml flask with 100 ml of 2N KCL. The flask is shaken on a wrist-action shaker for one hour at a setting of 5. Approximately 60 ml of the extract is decanted for analysis and the remaining extract and resin are discarded. The plastic lysimeter casing is returned to Fresno for cleaning and reuse.

5.7.2 Snow and Precipitation Chemistry

Similar to soil water we have two types of collection devices for atmospheric wet chemistry. The snowmelt collectors give an estimate of the variability in the precipitation chemistry during the wet season. The throughfall resin collectors give an annual measure of the total input from rain and snow during the period they are in the field. The resins are installed during the late summer and early fall and removed during the early summer of the following year; soil and though fall resins are placed in the field at the same time.

5.7.2.1 Snowmelt Collectors

The snowmelt collection system consists of tubing connected to underground collection jugs. The snow collects in the upper funnel with a 20.3 cm (8 in) round opening that narrows to a 2.5 cm (1 in) neck, melts and drains into a 5L jug. A glass fiber filter is placed in the neck opening to act as a coarse filter. The collection device is illustrated in Figures 5.7-2 and 5.7-3. These collectors are

co-located with the Prenart vacuum lysimeter and are placed immediately down slope about 2 m (6.6 ft) from the six Prenart tip locations (Figure 5.7-1). Since the vacuum lysimeters are located under the tree canopy the co-located collectors are throughfall collectors. A single snowmelt collector is placed in the nearest large opening and serves as a measure of incoming precipitation chemistry, i.e., no contact with overstory vegetation.

To recover the water from the underground canister, a vacuum hand pump is attached to the sample tubing, and the melt water is extracted into a collection bottle. Soil water and snowmelt water are collected at the same time from a location. The total volume of water that is found in the underground canister is documented, and a compiled sample is collected in a 125 mL Nalgene bottle for chemical analysis.

5.7.2.2 Throughfall Resin Collectors

One throughfall (aboveground) resin collector is placed at each watershed grid point (see Section 5.6). These collectors are placed on the ground and braced to be level between two wooden dowels that are driven into the ground. Two plastic wire ties are used to secure the collector to the dowels. This system was piloted for several years and seems to withstand the winter conditions quite well. Loss of resins is usually attributed to disturbance by animals but does not occur frequently. The throughfall resins are placed at the same time the below-grounds resins are installed (see Section 5.7.1). The throughfall resin collectors are built in the same way as the soil resin lysimeters except that the PVC pipe is longer (5.5 cm in length) and no sand or cheesecloth is used in their construction (see Section 5.6. 2).

5.7.3 Stream Water

Water samples are collected from the streams using two techniques. ISCO 6712 automated samplers draw water from the stream and store up to 24 samples before retrieval is required (Figure 5.7-4). At other times KREW personnel take grab samples directly from the stream. The sample size is always 125 ml for chemistry samples and 1000 mL for turbidity samples. For the purposes of this section the word “collection” refers to the water being drawn from the stream. The word “retrieval” refers to the samples being brought from the field to the laboratory in Fresno. The protocol for sample collection changes based on whether it is winter or summer.

During the winter season (November – May) automated samplers are used for collection since the temperatures inside the stream sheds remain cool enough to preserve the samples between weekly or bi-weekly field visits. The automated sampling collection schedule is altered based on the weather forecast in order to increase the probability of collecting storm samples. During two to four of the larger rain events each year, KREW is trying to do intensive sampling (> 5 samples per stream per storm). Over the last few years KREW has sampled four to six large rain events (> 5 cm total precipitation) each winter. Snow events are not intensively sampled

since the stream response is delayed until melt. When more samples are collected per day the number of retrieval visits must increase; therefore a balance is sought to reduce person hours for retrieval time during periods of clear weather.

Determining which of the automated samples to retrieve at the Providence Site is based on looking at the hydrograph for P303 and using the protocol described below. P303 is generally the most representative of the four Providence watersheds. By examining the hydrograph the flow data can be divided into one or more of the following categories. The number of samples to retrieve varies by category. Once the collection/retrieval decision has been made at P303, samples from the same dates and times are collected at the other three streams.

Flow Categories:

1) Base flow steady: Flow remains below 7 l/s (0.3 cfs).
    a. Two weeks or longer from last visit: Retrieve 2 samples and a grab sample.
    b. One week or less from last visit: Retrieve 1 samples and a grab sample.
2) Steadily rising hydrograph or falling hydrograph: Flows primarily between 6-20 l/s (0.2-0.7 cfs).
    a. Two weeks or longer since last visit: Retrieve 3 samples and a grab sample.
    b. One week or less since last visit: Retrieve 2 samples and a grab sample.
3) Steady high flow: Daily peak flows remain above 20 l/s (0.7 cfs).
    a. Retrieve 20:00 sample on every third day plus a grab sample.
4) Large storm event: Storm peak is greater than 30 l/s (1.1 cfs).
    a. Retrieve all samples with associated flows greater than 30 l/s on both the rising and falling limbs of hydrograph.
5) Mixed flow: (example: 1 week base flow followed by 1 week of rising hydrograph)
    a. Divide the time period into distinct periods where each period is at least 5 days long and fits either the base flow, rising hydrograph, or high flow description. If a large storm event occurs count that as a separate period (does not have to be 5 days long).
    b. For each of the distinct periods follow the retrieval instructions for that category.
6) Mixed flow which is completely erratic.
    a. Retrieve the 20:00 sample every other day.

To decide how to space the retrieved samples, count the number of samples that where collected since the last visit, divide that number by the number of samples (including the grab sample) that are to be retrieved. Retrieve samples at an interval of that whole number; however, the last sample should be the grab sample instead of the final multiple. As an example, if 22 bottles have been collected by the Isco and the flow data indicates that a steady base flow has

occurred, this information would mean that three samples (two samples and a grab sample) should be retrieved. To select the bottles that will be retrieved take 22 bottles divided by three samples equals 7.3, so the whole number sampling interval is 7. Therefore take samples from bottles 7 and 14 and a grab sample. The grab sample replaces the sample in bottle 21.

The following suspect samples are not taken at the time of retrieval: samples with the wrong volume and/or samples containing silt or debris when the flow has been below 6 l/s (0.2 cfs). To avoid a suspect sample take the first good sample immediately before it. All grab samples should be collected directly from the stream in a clean bottle. During retrieval, water samples are poured from the large 1-liter Isco bottle into a clean 125-ml Nalgene™ bottle. The Isco bottle is then put back into the sampler for the next use. This is a potential weakness in the design since the Isco bottles are not cleaned between samples and the possibility of cross-contamination exists. Logistically it would be extremely difficult to carry 96 1-liter bottles (24 per stream for 4 streams) in on skis or a snowmobile during the snowbound months. Thus, we assume that the few drops of water left in the Isco bottles are not enough to influence the next sample taken in the bottle. This assumption will be tested by comparing the chemical analyses of grab samples versus the samples collected in reused Isco bottles.

From June to October the collection and retrieval protocol becomes less complicated and includes making two grab samples per month at each stream. The Isco samplers are not used during this time since the stream shed temperatures are too high for sample integrity. Sample collection and retrieval are accomplished by KREW personnel for all streams on the same day. Fewer samples are required during this time of year because there are no storm events and the lack of precipitation produces a slowly declining hydrograph as the soil dries out and the groundwater table declines.

Regardless of season, all samples are stored in a cooler as soon as possible after retrieval and frozen immediately upon return to the Fresno laboratory. The majority of these samples would represent higher flow events, and only a small fraction would represent lower base flows. Frozen samples are packaged and sent off to the Riverside laboratory by Federal Express on a monthly basis in the winter and approximately every two months during the summer. The same shipment procedures described for the Prenart and snowmelt samples are used for the stream water samples (Section 5.7.1).

5.7.4 Laboratory Analyses

Stream water, soil water, and snowmelt samples are analyzed for cations (calcium, magnesium, potassium, sodium) and anions (chloride, nitrate, phosphate, sulfate) on a Dionex model DX600 Ion Chromatograph with a CS12 column. The PSW Riverside laboratory follows EPA Method 300.1 for both anions and cations; although the method is slightly modified for cations.

Analyses of resin lysimeter samples involve extracting the resin beads with KCl solution and analyzing the extract for nitrate (EPA Method 300.1) and phosphate (EPA Method 365.1) on a TRAACS 2000™ continuous flow analyzer. TRAACS uses a colorimetric method in which the samples are mixed with various chemicals that cause the anions and cations to develop a specific color. The intensity of the color is then recorded and compared against the color intensity of the calibration standards. Ammonium on both water and resin samples is also analyzed on the TRAACS 2000™ continuous flow analyzer following EPA Method 350.1. Alkalinity for all samples is determined EPA Method 310.2.

Standard reference material (SRM) and duplicates are included at the beginning and end of every run on every instrument. A chemist or trained lab technician analyzes and checks the SRMs, duplicates, and calibration curve to determine if the data is within specifications for quality assurance. The data is then electronically transferred from the instrument to the main database where it is reviewed by the data handler. The lab manager double checks all the data, calibration curves, duplicates, and SRMs before the data is released to KREW.

The pH and conductivity are measured on water samples in the field during sample collection using an Oakton CON-10 pH/electrical conductivity combination probe. The Oakton meter is calibrated at the beginning of each field sampling day and checked with standards in the middle of the sampling day.

5.8 Vegetation

The vegetation component of KREW maintains two major objectives: (1) to examine the response of the plant community of the watershed to treatments and (2) to characterize the riparian vegetation, its transition from bankfull edge to upland, and the extent to which it is affected by treatment to the adjacent upland. Therefore, sampling will take place in both riparian and upland areas throughout all eight watersheds. Since this study addresses the watershed level, the forest vegetation within a watershed is treated as a homogeneous community, regardless of where actual plant community boundaries may exist. KREW is not interested in quantifying the treatments themselves and will except whatever level of extension and intensity of disturbance the treatments produce. Furthermore, it is not the goal of KREW to examine direct effects of treatments on vegetation, but rather, how vegetation is affected by the treatment of the whole watershed. Treatments are likely to be patchy and not directly affect many of the existing vegetation transects; this is not perceived as a problem however, because each transect still falls within the larger, treated watershed. Natural thinning events prior to European settlement, such as wildfire, would also likely have been patchy, affecting some parts of the plant community directly and other parts indirectly.

Watershed (Upland) Transects (objective 1): Because the total area ranges from 48.7 ha (120.3 acres) for the smallest watershed to 227.7 ha (562.7 acres; Figure 4.1-2) on the largest

watershed, numbers of transects scaled to these proportions would be technically unfeasible if scaled down from the largest watershed, or statistically non-robust if scaled up from the smallest watershed. To strike a sensible compromise, 10 transects were assigned to the smallest watershed, 20 were assigned to the largest, and the remaining watersheds received 10-20 transects, depending on their size (Table 5.8-1). Transect location was then determined by dividing the watershed into partitions of roughly equal size, and randomly-selecting two soil grid points (see section 5.6.1) on which to locate transects in each partition, with larger watersheds containing more partitions as described above. At each chosen grid point, the long axis of the transect was determined by random azimuth, starting from the existing grid point and extending 20 m out in the direction of the azimuth.

Riparian Transects (objective 2): Transects were located at regular intervals, ranging from five to ten transects per channel, depending on the length of the channel. Because channel length is also quite variable on KREW watersheds (595-3170m; Table 4.1-1), transect numbers were assigned in similar fashion as with the upland transects, with five transects assigned to the watershed with the shortest channel, ten assigned to that with the longest channel, and the remaining receiving 5-10 transects, depending on channel length (Table 5.8-1, Figure 5.8). Transects were placed perpendicular to the stream channel, starting at the bankfull edge, and extending 20 m into the upland. It is common to sample using transects that are perpendicular to the stream channel when characterizing the riparian zone because the community changes frequently with varying lateral proximity to the channel (Bendix, 1994; Stromberg et al., 1996; Caicco, 1998; Winward, 2000). The location of transects rotate from one side to the other proceeding upstream, so as to sample opposing aspects of the watershed.

Sampling Protocol: Sampling protocol follows typical methods designed for thorough, yet repeatable and efficient vegetation classification (Daubenmire, 1968; Barbour et al., 1999). Minor modifications to those methods have been made to accommodate local concerns. Data collection on upland and riparian transects is identical with the following exception: to account for increased vegetation at the edge of the stream (the green line), riparian transects have two quadrats at 0 m, where upland transects contain only one. Sampling is expected to take place from June-August of every year until several years after treatments, resulting in at least two years each of pre-, interim, and post-treatment data: a total of 6 to 15 years of data. Four, (3 for upland transects) 1 X 1 m quadrats are placed along the 20 m transect line at 0, 5, and 10 m to sample herbaceous plant cover, with 2 locations at 0 m in riparian transects, each 2 m out from the center. The 5 and 10 m points are placed adjacent to the tape on the upstream side, so that the transect line makes up one edge of the quadrat (Figure 5.8). Percent cover will be estimated by species for all plants occurring under 1 m tall within each quadrat. In addition, woody seedlings < 1m tall will be counted in each quadrat to account for tree recruitment.

Table 5.8-1 – *Quantity of watershed and riparian transects for each of the eight KREW watersheds, as determined by the method described in the text above.*

Watershed	Watershed Transects	Riparian Transects	TOTAL
Providence 301	13	7	20
Providence 303	15	6	21
Providence 304	10	5	15
Duff 102	14	7	21
Bull 201	10	5	15
Bull 203	15	8	23
Bull 204	17	8	25
Teakettle 003	20	10	30
TOTAL	**114**	**56**	**170**

Shrub and canopy cover are estimated using the line-intercept method (Canfield 1941), by taking presence/absence data at every 1 m point along the line. This method was carried out by noting any woody species that intersected the plane of the line at two levels for each point: $\leq$ 2 m for shrubs and > 1 m for canopy cover. Intersection of the line by canopy cover was estimated by using a densitometer (commonly called a moosehorn). Cover will be determined, based on the percent of points each species is determined to intersect the line.

To sample tree cover, density, and recruitment, the transect was given an area that extends 5 m on either side of the line, resulting in a 10 X 20 m plot. All woody plants $\geq$ 2 m tall and rooted within the area of the plot were measured for diameter at breast height, and identified to species. Cover will be determined by species based on the basal area coverage of stems. Recruitment and density in terms of species and community can also be monitored in these “belt transects”.

Compositional differences will be analyzed to allow for the comparison of plant communities in treated vs. control watersheds, and the response of plant communities to environmental gradients. Seedling and tree recruitment, and tree density, will be analyzed using a one-way ANOVA or standard t-tests. These analyses permit a comparison of recruitment and density in treated vs. control watersheds. It is expected that treatments will not be directly applied consistently to all of the area of treated watersheds (i.e. the treatments will be patchy). Therefore, the sampling protocol has been designed to account for transects that may have burned or cleared only a portion of the transect. This design will allow for an additional scale of analysis other than the watershed-level scale. For example, within the watershed level, the effects of directly treated vs. untreated portions may be examined.

5.9 Fuel Loading

Ground, surface, understory, and overstory fuels will be measured during the field season immediately prior to and immediately following treatment applications. In addition, fuel moisture content, fire behavior measurements (flame length, rate of spread, and smoldering duration), and

fire weather data will be collected at the time fire treatments are applied. The protocol for these measurements has yet to be refined. However, methods for the fuel components (ground, surface, understory, and overstory) will closely match those of the Sequoia National Park site of the Fire/Fire Surrogate study (Knapp and Keeley, 2001); similar protocols are intended to facilitate data comparison between the two studies. Existing data from the first few years of collection at the Sequoia site will be used to gauge sample size and frequency of fuels measurements.

5.10 Stream Invertebrates

To be added.

5.11 Stream Algae

To be added.

6. Quality Assurance and Control

KREW's quality assurance and control objective is to reduce sources of error from the time of initial data collection to the time when data processing has been completed and the data is added to a Microsoft Access® database for final storage. To meet this objective KREW takes steps to: provide ongoing training to staff so that data collection and processing are performed in a standardized way; when possible, collect data in a redundant manner to provide a backup; perform audits to ensure the completeness of data; provide metadata to document data entry and processing procedures; and regularly calibrate and maintain equipment. KREW is assembling a wide variety of data types including: automated data collected by data loggers such as in the case of stream discharge and meteorology; manual field measurements such as those collected by KREW staff during stream channel characterization; and data coming from outsourced laboratory analysis as in the case of water samples and resin lysimeters. The specific manner by which quality assurance and control objective are met is different for each type of data.

6.1 Stream Discharge

Written protocols exist for all sample and data collection as well as instrument use and maintenance. New staff are trained by experienced personnel over a period of time until they become comfortable with the documented protocols and equipment maintenance. The stream discharge work is instrument intensive and requires knowledge of troubleshooting procedures on a number of stream instruments. The field books that accompany staff on field visits include the download protocols for all instruments and complete protocols exist for stream discharge site visits. These protocols were written in 2002 and have been updated when changes have occurred. A typical day involving a stream discharge site visit will involve working with Oakton pH/EC probes, Teledyne ISCO 6712 portable water samplers, Aquarod water level measurement instruments, Telog pressure transducers, Forest Technology Systems DTS-12 turbidity probes, a radio modem telemetry system, bubbler flow modules, 12-V solar configurations, Sontek YSI Flowtracker flow meters, as well as determining and correcting stage heights from the staff plates on weirs and flumes. It may take a new staff member months to gain a high comfort level to work with all these instruments.

The two flumes installed on a majority of the streams allow redundant discharge data to be collected for mid-range flows. One flume is larger and is intended to measure mid-range and high flows accurately; however, during low flows the measurement becomes less accurate. The smaller flumes accurately measure base flow through mid-range flows before being overtopped. A separate datalogger at each flume records the data and stores it until it is downloaded to a laptop during a field visit. Aquarod and Telog (refer to Section 5.1) dataloggers store stage data at the large flumes, while ISCO 6712 dataloggers used in conjunction with the 730 bubbler modules store discharge data at the small flumes. Having two devices provides backup data in

the event one device stops functioning correctly. The backup is most useful during mid-range flows. Additional manual stage measurements are recorded during field visits and are used to cross-check the automated discharge values. Currently, backup data (from Aquarods and Telogs) is downloaded to a laptop to transport it from the field to the office. Within 24 hours of the field visit the data is backed-up on a zip disk in the office and transferred to the server to await final processing. The water year ends on September 30. By the end of February of the following year all the discharge data will be processed by KREW. By March 30 a finalized, discharge data set will be permanently put in our archives.

The automated discharge data is audited by cross checking it with manual stage readings in the field. The readings produced by the bubblers can drift, and these manual audits can be used to reset the bubbler after a drift. The manual readings are kept in field books and also checked in the office when the discharge data is processed for final storage.

The measurement devices used to measure water level require a certain amount of maintenance. The Aquarod batteries are changed each September and February. Additionally, the stilling wells that house the Aquarods and Telogs collect sediment that must be cleaned out periodically. Checking the data from these devices on a regular basis is critical to monitoring the effectiveness and functionality of each device. Telogs will break under freezing conditions while Aquarods tend to drift after large storm events (possibly due to sediment buildup). The bubbler requires fresh desiccant, and this is replaced approximately every two weeks depending on the humidity. Bubbler lines will freeze and this results in flow level spikes that may last multiple days unless the line is thawed out. When a bubbler stage reading is found to have drifted from the manual reading by more than 5 mm (0.2 in) the bubbler is reset and a note is made to correct the drift in the data when processing occurs. When either the bubbler or backup device data differs substantially from the actual reading and there are signs that it is malfunctioning, the unit is removed and sent back to the manufacturer for repair. Spare equipment is carried for all field visits in case equipment has malfunctioned.

Discharge data require more processing than any other KREW data. This is due to: instrument drift; splicing data from the large flume and small flume together to capture all high and low flows during a typical year; and synthesizing data for one stream from another stream during periods of instrument failure or when a flume may be clogged with ice or debris. The ISCO bubbler data generally produces 90% of the annual hydrograph. The Aquarod is used to fill in gaps caused by bubbler malfunction or when the small flume is clogged or overtopped. The small flumes are overtopped in two or three storms per year and potentially during extended periods (1 to 4 weeks) during the spring runoff. To date, the following procedures have been used to process data. No post-processing is done to ISCO bubbler data from the small flume where the fluctuation looks completely natural and the bubbler was within 3 mm (0.12 in) of the visual reading at the start and end of the measurement period. When the ISCO bubbler data

from the small flume has fluctuations that look completely natural but the bubbler reading drifted from the visual reading by between 3 mm (0.12 in) and 10 mm (0.4 in) over the time period, the data will be corrected using offsets. When the ISCO bubbler data looks good overall but contains brief spikes that are not present in the Aquarod data for the same stream or in the hydrographs for the adjacent streams, then the spikes will be removed. In the event of the small flume being overtopped, data from the large flume will be spliced into the hydrograph. Since waves splash over the small flume once it rises to within approximately 7.6 cm (3 in) of its top, the large flume data will be spliced in once the level stays within 7.6 cm (3 in) of the top of the small flume for six hours. If the stage is within 7.6 cm (3 in) of the top of the small flume at any time during the day on consecutive days, the large flume data will be used instead of patching data sets together, which induces more opportunity for error than just using the larger flume data over the whole time period. When the ISCO bubbler fails to collect data or data is known to be erroneous, the backup data will be spliced into the hydrograph provided the flow is high enough to produce discharge results. If the discharge is very low, then a rating curve for the large flume could be useful in filling in the gap. Without a rating curve the data needs to be synthesized using data from other streams and a knowledge of how the stream discharges relate to each other; for example, B203 has had 10-20% higher discharge than B201 and 30-50% lower discharge than B204. All adjustments are documented clearly in a metadata file. If there is no data from either instrument but visual readings do exist and are two weeks or less apart and no large storms have occurred, then 15 minute data will be synthesized using neighboring streams for guidance. When data from either instrument and visual readings are not recorded, the data are left blank for such a period. Synthesized data are always documented in an honest and transparent way, and used to calculate yearly discharge totals. USGS synthesize data and believe that an accurate year of discharge must contain at least 90% real readings.

6.2 Meteorology

The Resource Binder for the KREW Permanent Weather Stations (Anderson, 2003) contains information covering all aspects of the maintenance and operation of the meteorology stations. The comments that were written into the programs for the CR10X datalogger are an additional source of information explaining the kinds of measurements that are being taken. These resources, as well as cross training between employees, is used for in-house training. The KREW staff that installed the weather stations and did the initial programming attended the Campbell Scientific CR10X and Loggernet Software training course. This course was excellent and would be ideal for new staff that must develop a more complete understanding of the meteorology stations.

The design of the meteorology portion of the experiment provides some redundant data. Having two stations per watershed site was intended to provide meteorological data across an elevational gradient; however, it also increases KREW's ability to collect a complete

meteorological record for each site even when equipment failures occur at one station. Additionally, on each tower there are two temperature sensors. The Vaisala HMP45C Temperature and Relative Humidity Sensor is the official sensor, but the Judd Depth Sensor also measures temperature and can be used if the Vaisala sensor fails.

Downloading the meteorology data and transporting it to the office follows a procedure similar to the stream discharge data. Field storage of meteorology data is done using Campbell Scientific CR10X dataloggers. The datalogger at each field station is programmed with measurement and processing instructions. Values recorded by the datalogger are stored in SRAM memory, which is backed up by a lithium battery so that even if the 12V system fails, no stored data will be lost. The datalogger is capable of storing 62,280 data points before the oldest information is written over; this provides a downloading window of approximately 2 months at each weather station. Data are downloaded from the office in Fresno via telemetry using the Forest Service radios approximately once per week. However, if the telemetry system fails, data can be downloaded to a laptop in the field and transported to Fresno. A protocol for this is provided in the Resource Binder. All visits, checks, adjustments, etc… to any instrument should be recorded in the appropriate field book, too much detail cannot be recorded (Osterhuber, 2003).

Sensors are verified, serviced and calibrated following the maintenance protocol outlined in Table 6.2-1 and fully explained below as well as in the Resource Binder mentioned earlier. Sensors will be sent back to the manufacturer for re-calibration at recommended intervals, or when suspect data are detected. KREW staff will make analog measurements of each variable during field visits at least once per month (two visits per month is ideal for winter conditions) to verify the measurements made at the field site by the electronic equipment. This will allow an instrument's reading (output) to be checked against a known "standard." Details of the protocol used to conduct these analog checks can be found in Table 6.2-2. The instruments used to carry out analog measurements are generally considered less accurate than those used for the digital measurements on the fixed stations. The analog checks are not intended to reveal minor inaccuracies with digital measurements, but merely to serve as an indicator of possible problems with the instruments. Furthermore, analog readings are not intended to ever substitute for a digital reading, as they are only taken once a month whereas digital readings are taken every 15 minutes.

Using the telemetry system, data checks are made twice a week of each sensor from the office to assure that sensors are functioning correctly and that values are within expected ranges for the season. Data between sites will be compared, and if an anomaly is found both sites can be compared to the California Data Exchange Center online data from the Tamarack Ridge site (Elevation: 2300 m, 11 km from Providence site, 24 km from Bull site). When suspect data are observed a field visit is made as soon as possible. Servicing and/or checking of the weather sites is more critical during or after storm events. "Servicing" may or may not include calibration, but

would certainly include checking each instrument's outward integrity, making sure they are free of debris and obstructions. Dust, vegetation, insects, standing water, and ice build-up are the most common foreign materials that may alter an instrument's function. (Osterhuber, 2003)

KREW staff will inspect data after each collection event to assure that sensors are functioning correctly and that values are within expected ranges for the season. Data audits could be done by comparing the two data sets of the meteorology stations in the same watershed site and by comparing those data to other data from the California Data Exchange Center website.

Processing meteorology data is being accomplished using the programming capabilities of the CR10X datalogger. Processing includes determining daily maximum and minimums, implementing an offset, setting a negative value to zero, or flagging off-scale values. Post collection data processing involves a number of aspects. A thorough check of all data is accomplished. This removes any data spikes, negative values, or erroneous readings. If data are lost, backup data are spliced into the series. This data may come from another instrument at the site, as in the case of temperature, or from the same instrument at another site. The most time consuming post collection processing is for precipitation. The gages fluctuate daily with temperature (primarily due to the long cable lengths between the gage and the CR10X logger) and this daily fluctuation must be removed from the record. Although precipitation is recorded and archived in 15 minute intervals, KREW only processes daily totals and 30 minute peak intensities.

Table 6.2-1—*Weather sensor maintenance intervals.*

Component	Recommended interval	Service to perform
Campbell Scientific CR10X Datalogger	Every time the datalogger's enclosure is opened	Replace desiccant
	Annually in September	Replace moth balls
	4 years	Replace internal lithium battery
Vaisala HMP45C Temperature and Relative Humidity Sensor	Every field visit (at least once a month)	Check radiation shield for debris or insect nesting, clean with water if needed.
	Annually during summer	Manufacturer recalibration Cost in 2006: $110 / unit
Kipp and Zonen CM3 Pyranometer	Every field visit (at least once a month)	Clean dust or debris from sensor window
	2 years	Manufacturer recalibration Cost in 2006: $90 / unit
Met One 013A Wind Speed Sensor	Every field visit (at least once a month)	Check that cups rotate freely
	Annually during summer	Inspect assembly for loose or damaged anemometer cups.
	2 years	Manufacturer recalibration and bearing replacement. Cost in 2006: $70 / unit
Met One 023A Wind Direction Sensor	Every field visit (at least once a month)	Inspect assembly for loose or damaged vane. Check that output matches compass directions.
	Annually during summer	Inspect sensor cables for corrosion.
	2 –3 years	Manufacturer replacement of potentiometer and factory overall. Cost in 2006: $80 / unit

Table 6.2-1 – Continued

Component	Recommended interval	Service to perform
Belfort 30" High Capacity Precipitation Gage	Annually in September	Drain and recharge antifreeze in bucket. Change CR10X offset for next water year so that annual precipitation total equals zero.
	Mid-winter servicing when bucket reaches 60 cm (23.6 in) of precipitation.	Drain and recharge antifreeze in bucket. Change CR10X offset so that annual precipitation total continues counting from current total.
	Annually in summer	Check that load cell's calibration remains valid. Lubricate load cell to prevent corrosion.
Tedea-Huntleigh 1042 Load Cell	Monthly during winter	Check that transducer's calibration is still valid.
Sensotec Pressure Transducer	Annually in summer	Check plumbing for leaks. Bleed transducer if reading doesn't appear accurate.

Table 6.2-2 – *Protocol used to carry out analog measurements of weather station parameters.*

Parameter	Description
Precipitation	Height of liquid inside gage determined by measuring with meter stick or tape measure.
Temperature	Temperature reading taken from separate, outdoor thermometer, mounted to station tower.
Relative Humidity	Relative Humidity determined with standard sling psychrometer reading, taken at the level of the humidity probe.
Wind Direction	Direction approximated over 30-second interval by human observation.
Wind Speed	Rotations of anemometer counted over 30-second interval, by human observation.
Solar Radiation	Pyranometer exposure to sun determined by human observation and classified into preset categories.
Snow Depth	Depth determined from meter stick and depth markings on nearby telemetry tower.
Snow Water Equivalence	Snow water equivalent measurements taken using Federal Standard snow tube sampler.

6.3 Stream Channel Characteristics and Geomorphology

Since quantitative measurements of some stream channel characteristics (,bankfull width, flood prone area width, riparian vegetation cover, bank angle, and cobble embeddedness) are based on the subjective identification and/or estimation of stream features, it is very important that the KREW staff be trained to standardize their observations as a group. Training includes going over protocols in the office and hands-on training in the field. KREW uses written protocols for each measurement to serve as a basis for training. The video "A Guide to Field Identification of Bankfull in the Western United States" (USDA Forest Service, 1995) is used to help standardize identification of bankfull with national efforts.

Much of the stream data are recorded by hand writing on field data sheets. Quality control checks are made at the end of each field collection period, generally each day, to ensure that each data sheet is complete and that no information is left blank. Field data sheets are transferred to the database. Original hardcopy field sheets are stored as a backup.

Survey data is electronically collected using a total station, and also written down in surveying notebooks.

6.4 Quality Assurance for Sediment

KREW is currently using sediment catchment basins to evaluate sediment production in the watershed as a result of the treatments. We incorporate three other sediment data parameters: turbidity and suspended sediment sampling, headcut measurements and sediment fences. Sediment fences and headcut measurements are a means of determining potential sources of sediment captured in the basins.

6.4.1 Sediment Catchment Basins

KREW assigns an experienced employee to train new employees in removing the sediment from a basin. Two crucial elements are to not siphon sediment out of the basin when you are trying to empty the water, and not destroying the basin liner at the bottom of the basin. An experienced KREW employee collects the representative sample.

The laboratory analysis of the sediment follows the written protocol (see section 5.4.2.2). Twice the volume of sediment will be taken from the basin as is necessary for the laboratory protocol. By doing this, half can be reserved and potentially reanalyzed in case something in the analysis is questioned.

Maintenance of the basins is done each year when they are emptied. A monthly visual estimate of what is in the basin is conducted to keep track of its stability.

6.4.2 Headcuts

The purpose of headcut measurement would be to increase the accuracy of the measurement of sediment loss directly caused by the treatments (thinning and burning). It is KREW's view that sediment that sloughs off a pre-existing headcut should not be attributed to the thinning or burning. Three years of baseline data should help determine background sediment production rates for the watersheds; however, headcuts do not produce the same amount of sediment every year and some years may produce an order of magnitude more sediment than the year before.

For headcut measurement to be a valuable tool, a precise surveying method to measure change in the headcut will have to be developed and followed; this has not been done to date. Each headcut will be measured once a year at the most, and there will not be any redundant data. KREW staff will attempt to find a surveying professional to review the method as no current member of the KREW staff is trained in three-dimensional surveying.

6.4.3 Sediment Fences

Sediment fences will illustrate which aspects of a thinning or burning operation significantly increase sediment. Is it the landings, or the skid roads, or wear and tear on existing roads that produces the sediment? Are the sediment increases that follow burning mostly coming off steep upland areas or from the riparian corridor? Do the fire lines around the burn create an important source of sediment? The sediment fences are not designed to improve the accuracy of the measurement of total sediment produced in a watershed.

If sediment fences are utilized by KREW, Lee McDonald, Colorado State University, will train the field staff. He will provide guidance as to how, when, and where the fences are installed. He will write a more detailed Quality Assurance and Quality Control section.

6.5 Turbidity and Suspended Sediment

Protocols have been established for turbidity monitoring, suspended sediment sampling, and SSC processing. Training of staff on the quality assurance procedures is a priority. Samples must be collected the same way each visit. In addition it will even be important to collect SSC samples from the same location at each site.

Since both grab samples and ISCO samples will be used in rating curve development, grab samples must be collected within 2 feet of the ISCO sampling arm outlet. In addition, it may be possible that ISCO and grab samples may produce different results. The ISCO pumps may not be able to pull some of the heavier suspended sediments up from the stream, or, in some cases, may even pump up bed load in the sampling process. Therefore, whenever possible, KREW will attempt to collect both ISCO and grab samples at the same time until it is determined that using the ISCO does not have a significant effect on the SSC results. Once this is

determined all samples will only come from the ISCO samplers. Even if someone is present at the site during a storm event, grab samples will be collected through the ISCO pump.

Like discharge data, continuous turbidity data is subject to erroneous spikes and drifting. These anomalies must be identified and corrected using the Flowlink software used for viewing and modifying ISCO data. Streamflow and meteorology data can be used to verify when storms were encountered and turbidity spikes were expected. If the wiper blades are not working properly the sensor face may become fouled with algal growth. This will result in a gradual increase in base turbidity data. As with discharge data, these drifts can be corrected for using the Flowlink program. In addition, false turbidity spikes are common from interference with sunlight. On some streams this is a regular occurrence and may be seen each day at the same time when the light penetrates the canopy. These spikes can be removed in Flowlink.

Forest Technology Systems recommends returning the probes each year for calibration. Due to the infrequent occurrence of storms in the late summer all probes will be removed and returned for calibration in late August or early September.

The SSC sample processing protocol has been used for many years by PSW Arcata and has many quality assurance procedures built in. Standard lab cleanliness is required. All filters and trays are only handled with tweezers to minimize the effect of fingerprints on the final sample weights. Dried filters are kept in a humidity free environment until they are weighed. Final SSC results are entered into the KREW database for final storage and use in the turbidity/SSC rating curve.

6.6 Quality Assurance for Soil Characteristics

This section will be included at a later date.

6.7 Quality Assurance for Water Chemistry

This section is subdivided into soil water, snow and precipitation water, stream water, and laboratory analysis.

6.7.1 Quality Assurance for Soil Water Chemistry

There are two different systems that allow KREW to analyze soil water chemistry -- Prenart vacuum lysimeters and soil resin lysimeters.

6.7.1.1 Prenart Vacuum Lysimeters

Staff is trained in the task of collecting water from the 1000 ml glass Prenart bottles and emptying it into a correctly labeled 125 ml Nalgene bottle. The main errors would be mislabeling and not screwing the Prenart bottle cap back on tight enough. This procedure is written in the back of the field book so people can refer to it.

Only long-term staff will be trained in trouble shooting the Prenart system. Ideally all of the tips should draw water. This rarely happens, but it is difficult to know if soil is dry or if there truly is a problem. There is a troubleshooting guide in the back of the Prenart field book and in the protocols binder.

The current system contains six tips at 13 cm (2.4 in) depth and six tips at 26 cm (10.2 in) depth. To a certain extent this shows small-scale spatial variation, but can also be viewed as a sample size of six at each depth. Data can be visually audited to determine which tips are consistently poor producers (unable to draw water from the soil). If the tip cannot draw at least 20 ml of sample five times a year we need to replace the tip. We will only replace tips in the summer.

The Prenart vacuum lysimeters tend to draw water from about the second storm each fall until about two months after the snow melts off the ground. The only thing that can be calibrated during this seven-month period is vacuum strength; the vacuum pump turns on at -0.25 bar and turns back off once vacuum reaches -0.5 bar.

Maintenance on the Prenart vacuum system is done in the summer. The glass bottles are taken down to Fresno for cleaning. They are then stored with plastic wrap covering the mouth to protect from contaminants. The tips and tubing cannot be removed so they will be left in place. The caps are left in place and have the open side duct taped shut. The two 12-volt batteries are left in the field and kept at 14.5 volts all summer. Each fall they are tested with a "crank tester" to determine if they still have sufficient amp hours. The system is reassembled in the field after two inches of precipitation have been recorded for the water year. They are turned on immediately after the second large storm. Staff record the volume of sample collected which indicates system health. Staff also record who collects the samples and if the vacuum pump apparatus was adjusted or anything was done to the photovoltaic system.

The soil surrounding the 12 tips does not dry out at a uniform pace. The pumps can usually compensate for one or two tips continually drawing air. Once three or more tips draw air the pump can not keep up and we loose the vacuum in all bottles and lines. To avoid this situation KREW staff shuts off the gate valve on tips which fail to work for two consecutive collection times. If a large storm comes in and rewets the soil then these closed off tips do not collect water.

Field duplicate and field blank samples are collected at a rate of 5%.

6.7.1.2 Soil Resin Lysimeters

Soil resin lysimeters go through four different stages in their approximately 18-month life. This section will analyze potential problems at each stage and what steps KREW is taking to mitigate these problems. This section is broken up by task and the various pieces of QA\QC are addressed within the task.

Construction of Resin Lysimeters

A written protocol exists for resin lysimeter construction. All resin lysimeters are assembled in the south lab of the Fresno, PSW building. Each new person will be trained and carefully watched the first day. New people do not assemble lysimeters alone unless they have at least a week of experience. Lysimeters are stored in zip lock bags labeled with the name of the assembler and date. Extra lysimeters are built to act as "blanks" for QA/QC purposes. These blank lysimeters are built in an amount of 5% of the total number of lysimeters to be installed.

Storage Prior to Field

The completed resin lysimeters are refrigerated until the day they are installed in the field. Resin lysimeters are discarded 8 months after they are assembled if they have not been placed in the field. Open bottles of resin beads are properly disposed of at the end of each year.

Placement in the Field

The following four steps are required to place lysimeters in the field: recognizing the bottom of the litter layer, getting the lysimeter completely under the undisturbed soil, removing the plastic cover, and writing the location on the lysimeter. The time the resin spends in the ground varies between 10-14 months. This is somewhat standardized by moving through the grid in a systematic pattern each year. All placements happen between June 1 and October 15. A written procedure is available and is taken in the field for reference. A new employee installs at least ten resins under the guidance of an experienced employee. All the installers are able to distinguish where soil litter stops and mineral soil begins. Once a week, every person is audited on one placement to make sure quality is not slipping. There is one lead person on each placement team. The lead is someone who has done several days of placement and is very conscientious about quality work.

Field Removal of Lysimeters and Shipment to Lab for Analysis

Field removal is typically done in conjunction with placement. It is important to make sure the location is written on the lysimeter and that the plastic is removed. At the end of each day, the collected lysimeters are rechecked to make sure every resin lysimeter is labeled. They are then put in labeled plastic bags and packaged into boxes. Ten full sites and a chain of custody form are placed in each box. These boxes are moved down to the PSW south lab every few weeks. If a whole grid point cannot be located, a team returns with the Trimble GPS unit to find it. If the grid point is located, but the lysimeters are not obvious, crews search for 20 minutes before placing the new lysimeters. Once the new ones are placed, the search for the old ones is abandoned. All retrieved lysimeters are stored in the temperature controlled south lab until all

the resins from that site are accounted for. Blank lysimeters are mailed to Riverside along with the lysimeters removed from the grid. The PSW Riverside chemistry lab has an excellent system of duplicates and replicates and they will manage the QAQC once the resins arrive.

6.7.2 Quality Assurance on Precipitation and Snowmelt Chemistry

This section is subdivided into precipitation resin lysimeters (throughfalls) and snowmelt collectors.

6.7.2.1 Precipitation Resin Lysimeters (Throughfalls)

Precipitation resin lysimeters are very similar to soil resin lysimeters (see section 6.7.1.2). The only additional component is that extra care must be exercised to install them completely vertically or they will under-capture throughfall and nutrient flux.

6.7.2.2 Snowmelt Collectors

Snowmelt collector assembly is straightforward and follows a written protocol. An experienced person trains new employees. Unlike resin lysimeters, mistakes during assembly are obvious by visual inspection. One person visually checks all 36 collectors before they go to the field in the fall. Each June, the collectors are removed from the field and brought back to Fresno where they are disassembled, washed, and dried. Depending on the condition of the pieces they are reassembled from the cleaned, old parts or new parts each fall.

Placement in the field also follows a written procedure. Most importantly, the rim of the collector is placed 8 cm (3 in) above the surrounding duff to avoid collecting surface flow. Because these collectors attract the attention of forest animals we try to put them out just before the first snow (late November). Because the snowpack in Providence is intermittent, they may become exposed several times during a winter. Maintenance can be performed whenever they are not covered in snow. The most common problems are that they tilt or sticks and/or bugs have fallen in the collector. Another maintenance issue is that squirrels chew through the sampling lines.

The goal of the collectors is to allow KREW to analyze the chemistry of the water that has melted from the snow pack since the last collection. The current design demands that 200-300 ml of water is left in the bottom of the collection container each time because the sample tubes bend over time. Therefore the water collected is an amalgamation of new water and 250 ml of older water. If it has been a fairly cold two week period you could have 200 ml of new water and 250 ml of old water, which would seem to compromise the study design. The current design has an opening area of 128 cm^2 (50 in^2). The 2001 design had a larger opening which collected more water and therefore did a better job of diluting the “old water”. An underground collection bottle with a narrower base would diminish this problem, as would attaching the sample tubing to the

bottom of the container to keep it from bending and ending up 2-3 cm off the bottom of the container.

This system does not have redundant data except that there are six snowmelt collectors on a 15-meter long line so you would expect similar chemistry, especially if the over story trees were the same species. Insects sometimes breed in the collection bottles especially in late spring.

Metadata would include the name of technician that collected the sample and what volume of water was withdrawn. The data could be audited for anomalously high nutrient levels, which might correlate to low sample volume. In these cases the water has most likely been sitting there for as long as a month and may contain organisms that change the chemistry.

As in all water chemistry retrieval the samples go in a cooler in the vehicle within 5 hours of collection and are put in the Fresno office freezer at the end of the field day.

6.7.2.3 Quality Assurance for Stream Water Sampling

There are three questions associated with any year around the stream water chemistry-sampling program. First, when do you draw the sample? Second, is that sample representative of the stream water when it enters the Isco bottle? Third, does the chemistry change as it sits in the sample bottle in a sometimes-warm sampler shed?

The various sampling schemes used to program the Isco 6712 samplers are covered in methods (section 5.7.3). KREW staff is trained in how to program the samplers and there is an extra sampler in the Fresno office to allow staff to practice programs. When sampling is based on time, all samplers are programmed to draw water at the same clock time.

The samplers collect 20 - 24 samples between winter visits (usually 2 weeks) but a smaller sub sample of these are actually retrieved and sent away to be analyzed. This over sampling allows KREW to not retrieve samples that appear suspect. A suspect bottle is one with the wrong volume or excessive sediment when the discharge at the time of sampling could not have suspended that material. Three times a year a grab sample will be taken at the exact same time as an Isco sample. This redundant sampling will help us to catch contamination problems in the sampler intake line. The redundant sampling will not happen mid summer as we do not take automated samples mid summer.

Whenever a stream is visited, a grab sample is taken and these are sent off to the lab along with one to two samples taken by the automated Isco sampler earlier in the two-week period. The grab sample, which is frozen within hours, should be a slightly higher quality than the automated sampler collected samples. KREW will graph a nutrient's concentration in the stream throughout the year using all samples, only Isco taken samples, and finally only grab samples. Using this information KREW will re-evaluate whether more or less grab samples are needed.

Also a cut off time in the spring could be set when leaving samples in the shed for ten days is no longer acceptable.

In the summer of 2002 KREW analyzed how chemistry composition changed for samples left in the shed over the course of five warm days. This study, Chemistry Time Study, is in the protocols binder. For a brief time, chloride, nitrate, and ammonium levels changed significantly and quickly when left in the shed. Sulfate and phosphate started at zero and remained there indicating little change.

Isco intake hoses will be replaced on an annual basis. Isco sampler bottles and the low flow intakes will be taken out, washed, and put back on an annual basis. Since we are analyzing suspended sediment, sample intake line speeds will be measured to catch failing motors. Since at this time the ISCO samplers are not used during the summer, the best time to do the "clean and put back" would be in the late fall when it is cool enough to return to automated sampling and access is easy.

6.8 Vegetation

All data will be collected in 2-person teams, including the lead botanist, ensuring that all crewmembers are properly and consistently trained. Once the sampling protocol is established, amendments to the system will be minimal, so that data are as comparable as possible from year to year. Any new staff hired to sample vegetation will follow the original protocol, including sources used to identify plant species.

It is expected that vegetation data will be used to refine the sampling design, by calculating variance, error and precision, and adjusting the design accordingly. This adjustment will be carried out using the first field season of data. Subsequent seasons will then remain consistent until the termination of the project. Data will be entered into a Microsoft Access database that will be designed according to efficient transfer from field data sheets to the computer. Data entry will be carried out promptly, during or directly after the field season by at least one of the people present during data collection. This will ensure that field notes can be interpreted accurately. All data entry will be subjected to double-checking by a different researcher or entered twice by two different researchers and checked for mismatches. All data will have corresponding dates and collector names, to facilitate archiving. Data are maintained in a Microsoft Access database, with fields that correspond with Access databases from other components of the project, to facilitate dataset merging.

6.9 Fuel Loading

Since a full season of data collection on fuel loading will not take place until 2004, the details of quality assurance and quality control have not been refined. However, it is expected that most of what is stated above in vegetation will apply to fuel loading data. KREW anticipates data sharing

with the Sequoia/Kings Canyon site of the Fire/Fire Surrogate Study for this module; this will likely subject each study to further checks and balances. Researchers working with vegetation data will also collect and enter fuel loading data during the field seasons designated for fuel loading data collection.

7. Animal Care and Use Certification and Permits

Carolyn Hunsaker and David Herbst have collection permits issued by the California Department of Fish and Game for invertebrate sampling.

8. Radio Telemetry and Communications Considerations

The KREW study has 14 remote instrument locations that collect data all year long. During the winter when storms and flood events are more common loggers need to be downloaded and inspected regularly to insure that high quality data are being collected. Getting to each site involves at least 1.5 hours of driving, plus an additional hour of skiing or snowmobiling when access roads are blocked by snow; therefore, manual retrieval of data from a remote system is a huge commitment of personnel time. For these reasons a telemetry system to allow remote instrument checks and a daily data download was implemented.

In December 2000, KREW completed a survey of 14 experimental watersheds to determine the requirements and feasibility of a remote telemetry system. There was universal agreement that it was desirable to be able to remotely access data, but only one watershed study, Reynold's Creek, had a telemetry system that worked well. In order to prevent failure, the Reynold's Creek study recommended contracting the telemetry installation out to a skilled professional. A visit in the summer of 2001 showed that Reynold's Creek has topography and vegetation that is more conducive to telemetry than that found at KREW. In many cases you can see from the remote site to the base computer using binoculars. The Reynolds Creek telemetry system uses Motorola radios for data transmission.

KREW needed to retrieve data from Isco 6712 samplers and Campbell CR10X data loggers using Bendix King radios so we could easily tie into the existing Sierra National Forest (SNF) repeaters. Thus the SNF radio communications staff would help us maintain our system long term. Although Isco and Campbell both sell telemetry systems, they use other radio brands custom designed to work with their proprietary software. Their systems are also designed for short telemetry runs without repeaters. Neither company was willing to attempt to work with our Bendix King radios and repeaters. Isco suggested we contact an "integrator company", specifically Wireless Communications of Denver, Colorado.

KREW staff spent several months investigating private sector options. KREW was hesitant to put an integrated technology contract out to bid that had many unknowns and was above $25,000. Upon talking to the PSW Albany contracting specialist, they insisted that the technology branch of the Forest Service would need to write the contract. Chuck Richmond and Frank Ealands suggested we contact Mike McDonald of the radio communications staff on the Sequoia National Forest for recommendations. He suggested a "packet" radio technology and thought he could make it work in a week. The Angeles National Forest was successfully using this system, which involves sending packets of data with each transmission, for data retrieval. His efforts to make "packet" radio work with Isco samplers were unsuccessful. The problem seemed to lie with "time outs"; the fact that the Isco samplers did not wait long enough for a reply before they repeated their request for information. At that time it was not possible to change the timing of

the “time out” in the sampler or in the Isco Flowlink™ program. Mike McDonald felt this was a significant obstacle and could not invest more time on the project.

Starting in June 2002, KREW contacted the USFS Missoula Technology Center. Ted Etter and his subcontracted software personnel spent several months trying to get the system to work without repeaters in Missoula. They convinced Isco to rewrite the Flowlink software so the “base” computers “time out” could be adjusted. By October they had a system that worked in their office for both the Isco 6712 samplers and the Campbell data loggers.

In November, Ted Etter installed modems, interface boxes, radios, and antennae at nine KREW sites. A computer in the office was dedicated to telemetry and attached to a high-gain YAGI™ antennae. No data downloaded to Fresno but one site did download via the repeater to a field laptop. In hindsight, Ted Etter identified two major problems. First, the “time out” in the Flowlink software in the base computer had been fixed but the individual samplers were still not waiting long enough for a reply. This flaw had been missed in the Missoula tests because they did not use a repeater. Secondly, the signal strengths out of the Providence Site were too weak.

Since then, a firmware patch has been written so the “time out” in the Isco 6712 sampler can be adjusted. The signal paths from all sites to the repeater have been mapped and the signal strengths improved. Many of the sites seemed unlikely to get strong enough signals for data, although voice transmission was tested in 2002 and worked. These sites have been retrofitted with directional YAGI antennae that points to a passive repeater site on the nearest ridge. The passive repeater and the new antennae were tested and permanently installed in June 2003. Currently, nine stream instrument locations and all four meteorology stations have been equipped with working radio telemetry installations. A program has been written which allows automatic downloads of all ISCO samplers each morning. This allows all the data to be checked each day from the office and problems can be identified and corrected as soon as possible. Some intermittent communication problems continue to occur, especially during winter months.

As of April 2007, roughly $65,000 has gone to the USFS Missoula Technology Center for design and implementation of the KREW telemetry system. KREW staff and other USFS personnel have spent approximately $20,000 in personnel time. In 2004-2005 all radio telemetry equipment was placed in weather proofed, protective enclosures and operation has improved. Ted Etter visits KREW each year to service telemetry equipment.

Note: Additional technology besides radio based telemetry was considered. Cell phone technology was rejected for coverage and reliability reasons. Satellite telemetry was considered but also rejected. Although other projects have used this technology to retrieve data, KREW felt that committing funds to this technology was risky. In 2001, the providers were losing money, and we did not want to purchase hardware only to have it become obsolete if the company failed. Costs were also a concern.

9. Data Management and Archiving

KREW data are collected in a number of different forms. The QA/QC path that data takes after collection varies (see section 6) but after being processed it will eventually be added to a Microsoft Access database that is still under construction. Some data are gathered and temporarily stored in data loggers (all meteorological data and water stage data from ISCO bubblers and Aquarods), some data are produced by the PSW Riverside chemistry laboratory, while other data are collected in the field on paper forms. Work is underway to have meteorological data and water stage data from ISCO bubblers sent once a day via telemetry over the Forest Service radio network to a PC in the Fresno office where it will be processed and added to the Access database. We plan to have the chemistry data processed by the PSW Riverside laboratory imported directly into an Access database and that database sent to the Fresno office. Both of these goals should be met in 2003.

Data that are gathered in the field on paper forms will be entered into an Access database and checked for errors. This can be done by having two different people enter the data and discrepancies identified by a computer and corrected by a person. It can also be done by entering data into a database and then having a different person check the database against the paper forms for discrepancies. In all situations, one of these approaches will be used.

The primary database will reside on the Fresno office server and will be backed up by the office computer staff every evening between Monday and Friday. The tapes used for back-ups between Monday and Thursday are re-written every week. The Friday tapes are archived and kept for two years. The tapes from every other Friday are sent to the PSW station in Albany, CA for offsite storage. The tapes that are not sent to Albany remain at the Fresno lab. The tapes that go to Albany are sent every two months in a batch rather than sending one tape every other Friday. On a monthly basis the KREW staff will make a secondary copy of the database that will be stored on CDs in the Fresno office. At the end of each water year (September 30) the Access database for that year will be archived and a fresh database for the next year begun. This procedure is meant to prevent the database from becoming larger then the maximum size that the software can handle.

10. Expected Products

To be added later.

11. Budget, Staff, and Time Requirements

This chapter is broken into four parts: expenditures, funding sources, possible future additions, and timeline for study implementation.

11.1 Expenditures

The KREW study, including all nine study modules (discharge, meteorology, channel characteristics, sediment, soil characteristics, water chemistry, vegetation, fuel loading, invertebrates), will cost about $615,000 annually as proposed at this time. The budget presented is a prediction of costs to collect data from and maintain the nine existing study modules for eight watersheds, but not to expand any of them or add new modules (Table 11-1).

Four of these modules (discharge, meteorology, sediment, water chemistry) have high front-end instrument and construction costs. These front-end costs are 80% paid for now and will be 95% paid for by the end of 2003. We are in the first year of baseline data collection for these four modules at the Providence Site. The KREW study is similar to other large watershed studies in that the cost breakdown is shifting from being mostly instrument costs to being mostly salary costs. It is difficult to breakdown cost on a study module basis. A rough breakdown of the 2004 anticipated expenses (assuming no new instruments) is listed below:

Full time staff salaries	51%	$314,000
Seasonal salaries	8%	$51,000
Chemistry costs	17%	$106,000
Cooperative agreements	10%	$60,000
Maintaining instruments	6%	$33,500 (Table 11.2)
Vehicles	4%	$23,000
Other	4%	$26,000

11.2 Funding Sources

Since 1999, the USDA Forest Service, Pacific Southwest Research Station (PSW) has been a large contributor to the KREW study. It pays the salaries of the principal investigator and lead hydrologist, and provides computer and administrative support. PSW also provides office space and some seasonal housing. KREW is part of the Sierra Nevada Research Center, which is a unit of PSW.

National Fire Plan dollars were allocated in 2001 and allowed us to purchase the majority of the instruments and paid for the seasonal labor to install these instruments. This money also allowed us to bring on a full time GS-9 hydrologist and GS-7 hydrologic technician who do the majority of the field data collection for the discharge, meteorology, sediment, and water chemistry modules. National Fire Plan dollars permitted us to enter into the joint agreements with three universities to assist us on modules where we lacked expertise.

The Joint Fire Science Program (JFSP) funding has helped pay for water chemistry work and public outreach since 2000. The Providence Site is a JFSP demonstration site for fuels reduction and evaluation of associated effects. This grant also supports eastern Sierra Nevada demonstration site where Dale Johnson, University of Nevada, Reno, is the lead scientist. KREW has submitted a proposal to JFSP to support the vegetation and fuel loading modules of KREW for the next three years; if funded this would primarily cover the plant ecologist's salary.

The Providence Site contains Southern California Edison land, and they will assist with treatment implementation. We do not expect funds from them to operate KREW.

The Sierra National Forest is a partner in KREW and provides invaluable support. The study is on their land, they maintain the access roads, and they will take care of NEPA compliance. The Forest silviculturist and fuels management officer are helping with the design and will implement the treatments. Their soil scientist, hydrologist, aquatic ecologist, and botanist all provide input to KREW.

In 2005 California State funds were awarded through the California Bay-Delta Program (chemistry costs, data manager position, instruments for two integrating stations, a stream algae module, continued invertebrate monitoring, and turbidity monitoring).

11.3 Possible Future Additions to KREW Study

The following items would compliment the current study, but currently lack funding.

- All nine study modules will produce data in 2004 from all eight watersheds. KREW is hoping to hire a data manager to maintain this large database.
- Integrating stations allow researchers to see if observed effects on the first order streams can be detected further down the stream. They would also allow us to address cumulative effects in a quantitative manner. KREW is proposing to build two integrating sites (one each) on the main stems of Providence and Bull creeks.
- Sediment load measurements are currently done entirely from analyzing what is captured in the sediment catchment basins. KREW would like to supplement this with analyzing samples drawn at specific turbidity levels. This requires purchasing turbidity probes.
- Currently KREW analyzes pH and electrical conductivity at the Riverside laboratory. If KREW purchased probes this could be done in-situ in the streams and reduce laboratory costs.
- Carbon content and cycling work to facilitate usefulness for climate change research.
- KREW would like to locate funding to support a stream algae module.
- Channel morphology requires surveying equipment, which KREW is currently attempting to rent or borrow. Owning a total station would facilitate channel morphology and sediment pond measurements.

- Another set of four watersheds would greatly strengthen the conclusion drawn from the KREW study, but does not seem feasible at this time.
- An amphibian module would fit well into KREW.
- Two more watersheds in the Teakettle Experimental Forest (Bull Site) have been discussed for prescribed fire treatments.

11.4 Timeline for Study Implementation

The KREW study was initially envisioned with three years of pretreatment baseline data collection, one year of treatments and seven to ten years of post treatment monitoring. Equipment acquisition and installation has taken longer than expected and realistically treatments will take longer than a year.

1999 and 2000 were primarily spent choosing study watersheds and searching for funding. Pilot soil water chemistry studies and macroinvertebrate studies were initiated in 1999. The groundwork was laid for cooperative agreements with universities to design and implement selected study modules. Water samples and discharge data were manually collected on 16 streams to determine which best fit the study criteria. Some flumes and sediment ponds were installed in 2000.

During the summers of 2001 and 2002 KREW increased seasonal staffing levels and installed most of the instruments necessary for the discharge, meteorology, sediment, and water chemistry modules. At the Providence Creek site the first year of baseline data collection for these four study modules began on 1 October 2002. At the Bull site baseline data will start 1 October 2003. Aquatic invertebrate baseline data collection began in the spring of 2002. Baseline data collection for vegetation, channel morphology, and soil characteristics will start in the summer of 2003 in both the Providence and Bull sites. Fuel loading will not be an annual measurement and will be done for the first time during either the 2004 or 2005 summer.

Burning and thinning on eight watersheds covering close to 1000 ha (2500 acres) is more logistically complicated than KREW staff realized. The absolute minimum time to complete the treatments would be 18 months (September 2005 through the spring of 2007) because the slash created by thinning must dry for a year before it will carry fire. Twenty-four or even 30 months is a more realistic timeline to get all eight watersheds treated. Post treatment data may start on 1 October 2007 at the Providence Site depending on the treatment implementation. KREW staff are asking the Sierra National Forest to do all the thinning in one year and all the burning the following year. This may not be logistically possible.

Table 11-1—*Annual costs to run the KREW study*.

Item	Total for category	Costs	Type of expense
Full time staff	314,000		
Principal Investigator (GS-13)		108,000	Permanent
Lead Hydrologist (GS-11)		65,200	Permanent
Hydrologist (GS-9)		50,300	Term
Ecologist (GS-9)		51,000	Term
Hydrologic Tech. (GS-7)		40,000	Term
Part time or Seasonal	51,100		
Hydrologic Tech. (GS-6) 17 pp (s)		24,000	Adjustable
Student assistant (GS-4) (part time)		10,400	Adjustable
Student assistant (GS-3) (part time)		5,000	Adjustable
SCA Long term (5 months)		9,000	Discretionary
SCA Short term (2.5 months)		2,700	Discretionary
Local student hire (free in 2003)		0	Discretionary
Vehicles	23,000		
4 permanent vehicles		18,000	Permanent
4 vehicles which we borrow seasonally		5,000	Discretionary
Cooperative Agreements	60,000		
UCSB - Invertebrate		25,000	Standard
U Reno - Soils		15,000	Standard
Fresno State Geology, Channel morphology		20,000	Adjustable
Chemistry costs	106,362		
Stream water = 8 streams*(52 weekly + 16 storms) * 10 parameters* $6/parameter		32,640	Adjust frequency or # of parameters
Vacuum lysimeter= 4sites * 12 bottles *10 times * 10 parameters * 6/parameter		28,800	Adjust frequency or # of parameters
Snowmelts= 4 sites*7 bottles * 8 times * 10 parameters*6		13,440	Adjust frequency or # of parameters
1,431 resins * 3 parameters +extraction- not done until 2004 estimate =$22		31,482	Adjust frequency or # of parameters
Maintaining existing field instruments	33,500	(Table 11.2)	Average year
Soil lysimeters & throughfalls rebuild 1,431	5,000		Standard
Snowmelt rebuild	500		Standard
GPS subscribe, snowmobile maintain, tools	4,000		Standard
Fed-ex shipping of samples	1,000		Standard
Travel and Training (5 employees)	15,000		Adjustable
Vegetation survey supplies	500		Standard
Channel morphology supplies	1,000		Standard
Total cost to maintain existing studies	614,962		

Table 11-2—*Annual instrument maintenance costs.*

Cost to maintain field instruments									
Item	# of units	Total value	% replaced per year	Replacement cost (main unit)	Replace time (person weeks)	Upgrade/minor repairs	Upgrade time (person /weeks)	Total $ annually	Total time annually (weeks)
Flumes	14	$35,000	0.05	$1,750	6	$2,000	3	$3,750	9
Isco 730 bubblers	8	$14,400	0.4	$5,760	1	$0	1	$5,760	2
6712 water samplers	8	$24,000	0.15	$3,600	0.5	$300	0.5	$3,900	1
Sampling arm	8	$800	0.2	$160	0.5	$0	0.5	$160	1
Sediment ponds (pond liner)	6	$7,200	0.15	$1,080	3	$0	0	$1,080	3
Vacuum lysimeter (pump, bottles, lines, tips)	4	$12,000	0.25	$3,000	0.5	$300	1	$3,300	1.5
Weather stations (tower =$5,500, precip. gauge =$8,500, snow pillow =$3,600)	4	$72,000	0.07	$5,000	3	$1,400	2	$6,400	5
Grid markers (posts and tags, earth staples)	470	$4,700	0.05	$235	1			$235	1
Solar system (panel, controller, batteries, wire)	12	$12,000	0.1	$1,200	2	$1,500	1	$2,700	3
Instrument sheds	12	$14,400	0.08	$1,152	6	$1,000	1	$2,152	7
Telemetry (13 radios, 15 antennae, 13 modems etc)	13	$25,000	0.15	$3,750	1	$300	1	$4,050	2
Total cost to maintain field instruments								**$33,487**	**35.5 Per/wks**

12. Opportunities for Partnerships and Collaboration

Several agreements are in place with universities and other agencies, and we anticipate additional ones will develop. As the Sierra Nevada Research Institute develops at UC Merced, opportunities for both graduate students and faculty will be explored.

Dr. Dale Johnson, University of Nevada, Reno

Dr. David Herbst, University of California, Santa Barbara, California

Dr. Fredericka Harmsen, California State University, Fresno, California

Dr. Steven Blumenshine, California State University, Fresno, California

Dr. Larry Brown, U.S. Geological Survey, Sacramento, California

Current funding sources are the Forest Service's National Fire Plan and the Sierra Nevada Research Center, the Joint Fire Science Program, and the California Water Institute at California State University, Fresno. In 2005 California State funds were awarded through the California Bay-Delta Program ($661,000, State Agreement No. 04-186-555-0).

13. Establishment of Oversight Team

Will be established after peer review.

14. Statistical Review

Jim Baldwin, PSW statistician, is part of the team developing this research. The final document will be review by a PSW statistician.

15. Health and Safety

The KREW staff follows all of the safety procedures outlined by the Forest Service, PSW Research Station, and the Sierra Nevada Research Center.

Job Hazard Analysis (JHA)

There are four JHA that are read and signed by all employees when they start work: Watershed project (guide to all other JHAs), General field work, Radio use, and Vehicle travel.

There are ten other JHA which people who perform the stated tasks follow: operating all terrain vehicles (ATV), using chain saws, tree climbing, using hand power tools (Dewalts), hanta-virus, handling resin beads, operating shop power tools, ski and snowshoe travel, operating snow mobiles, and conducting stream surveys. All of these are kept in the Watershed Safety Binder.

Emergency Evacuation Procedures (EEP)

There are two Emergency Evacuation plans (EEP) in the Watershed Project JHA; one for winter and one for summer. These detail who to contact and how to evacuate an injured person.

Material Safety Data Sheets (MSDS)

The watershed project uses four products that need MSDS: gas, antifreeze for snow pillows, resin beads, and chain saw oil. These MSDS will be in the Fresno office and at Glen Meadow during the summer.

Laboratory Work

At this time the watershed group does not do any “lab work”. All of our chemistry analysis is done at the Riverside Lab. If we do start chemistry analysis we will follow all OSHA protocols for labs.

Training

- Supervisors hold tailgate safety sessions approximately every two weeks, but at least once a month. Brief summaries are kept in the safety binder.
- Supervisors try to make one safety comment (one sentence) that is a key point from a JHA each day.
- Employees are trained on individual tasks is outlined in the JHAs.
- All employees receive a basic 6-hour first aid course.
- We are considering sending selected supervisors to a *Safety for first line supervisor’s* course. This is more about avoiding accidents, which is probably more important than knowing first aid. We are also evaluating whether field supervisors should get slightly more first aid training (i.e., 16-hour Wilderness First Aid certificate).

Preventative actions

- Personal protective equipment (PPE) are made available and used. The primary PPE during construction are eye protection. Closely following are ear protection, gloves, hardhat, and proper footwear. Eye protection and gloves are assigned to each employee at the start of the season. Ear protection is kept in the toolboxes and hardhats will be kept in the trucks.
- JHA are prepared for all dangerous tasks (see above).
- Each Site (Bull, Providence, and Teakettle) has a shed or building equipped with winter survival gear so people can stay out one night if necessary. This means that employees would always be within two miles of the vehicle or the survival shed. Actual work time (not travel) would be spent primarily within 1.2 km (.75 mi) of the survival gear.
- When people work alone in the winter their actions are tracked by radio communication to hopefully enable us to reach them before dark in the event of an accident.
- During the summer there will be a sign-out dry erase board at Glen Meadow. All employees will be encouraged to use it every day, but it will be 100% mandatory for people working alone.

Documenting

- Employees are encouraged to promptly report all injuries and fill out either a CA-1 or CA-2.
- The single person ski forms are archived (see JHA for details).
- The tailgate safety talks are archived.
- Copies of people's various licenses (driver's, chainsaw, ATV) are kept by Sandy Hicks in the Fresno office.

Review

The watershed staff will review the accidents that occurred in the past year each January and try to make systematic changes to avoid them the following year.

Here are the reviews for the first three years:

- 2000 – An SCA volunteer aggravated a pre-existing knee injury probably by trying to slow down heavy wheelbarrows on steep slopes; resulted in lighter work for 2 weeks.
- 2001 – A government employee injured his back carrying 80 lb bags of cement down a steep drainage to a flume. We have strived to buy 60 lbs bags and have used ATVs to transport them where possible. The employee recovered after a chiropractor visit.
- 2002 – No injuries.

See appendix Watershed Project JHA for more information. This still needs to be attached, but because it is a landscape form it often messes up the document; therefore, it is not presently attached.

16. NEPA Compliance

Numerous site visits were made and reports were prepared by High Sierra Ranger District staff for each of the instrument locations; these are on file at the Prather office. The management treatments for this research will be covered under the Programmatic EIS for the Kings River Project; this document was started in October of 2003. The final EIS was issued in December 2006. A lawsuit was filed against the project in 2007, thus the KREW treatments have not been implemented.

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18. Appendices

List of Appendices

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18.1 Flume construction specifications

All flumes shall be molded of structural Fiberglass reinforced polyester. The interior surface shall have a minimum of 10 to 15 mil ultraviolet-resistant smooth gel-coat. The tensile strength at break shall be 15000 PSI min, ASTM D638, flexural strength of 25,000 PSI min. ASTMD 790, and a tangent modular elasticity of 1,000,000 PSI min. ASTMD 790. The flumes shall be reinforced with stiffeners down the sides and across the bottom. The flumes shall have a continuous flange on the top of each wall not less than 2“ wide. The flumes shall have two 2” anchor clips located on both side walls.

Quantity Requested**:** One 6-inch Parshall-Montana
Date desired: July 9 or July 16 Please UPS or Fed Ex this flume

Options and Modifications:

1) The modified Parshall (Montana) flumes shall be terminated at a distance of 6 inches horizontally from the smallest contraction of the converging section. The entire diverging section of the flume is eliminated.
2) Locate four, 2-inch anchor clips on the sidewalls and flush with the flume floor at a distance 4 inches from the entrance and 10 inches from the discharge end.
3) The sidewall shall be terminated (18 inches) above the floor. Free board is being minimized since this will be installed so that floods transport material over it.
4) Install a permanent bubbler tube to take a 1/8 inch vinyl bubble line from an ISCO model 730 bubbler flow module on the **right** side on the flume facing downstream.

5) Attach, or laminate in, a **metric** staff gauge on the same wall as the bubbler (right). Make it one of the easy to read type with staidia rod type numbers.
6) Attach one 8-inch integral stilling well located at the point of measurement on the left wall (facing downstream), with two ports.

18.2 Rejected Stage Recorders

Why other stage recorders were rejected:

Submerged pressure transducers were rejected because freezing destroys them and KREW stilling wells froze solid in Feb of 2002.

Ultrasonic sensors were rejected because of higher power requirements (24 volts) and cost.

Floats have several mechanical pieces which can malfunction and are more difficult to tie into data logger.

18.3 Rejected Flumes and Weirs

Why other Flow Measuring devices which were eliminated.

Weirs were eliminated because:

1) They are not accurate down to 0.5 l/s because the flow adheres to the weir plate.
2) Weirs require large upstream weir ponds to diminish velocity. These ponds can not be constructed in these streams without constructing a wall 4.5-feet high.
3) One stream, Teakettle 3, will use a weir as it is already in existence (constructed 1939), it's low flows stay above 3 l/s and there is already a robust dataset from that location.

H-flumes where considered as they can measure very wide range of flows but most hydrologist felt they were more likely to clog.

Double flumes (small flume fits inside the larger one**)** were considered but if the smaller flume could not be removed before an incoming storm all data would be lost.

Trapezoidal flumes could have been designed to measure the whole flow range accurately (it worked when modeled on the computer). However, KREW would have been the only watershed study using the device. Also the fabrication cost was $9,000 and the flume would have been extremely difficult to transport.

Cutthroat flumes are very similar to Parshall Montana flume. They were not chosen because KREW didn't know of anyone with experience with them.

18.4 SCI field protocol measurement sheets (to be inserted in final document)

18.5 Herbst physical habitat data sheets and associated code form (to be inserted in final document)

18.6 Characterization data sheet for resin lysimeter grid points (to be inserted in final document)

18.7 Protocol for alternate placement of lysimeters in case of interference (to be inserted final document)

18.8 Codes for Labeling Lysimeters at Time of Installation (to be inserted in final document)

18.9 Study Plan Reviewers

The following persons participated in a study plan review conducted on May 6-8, 2003.

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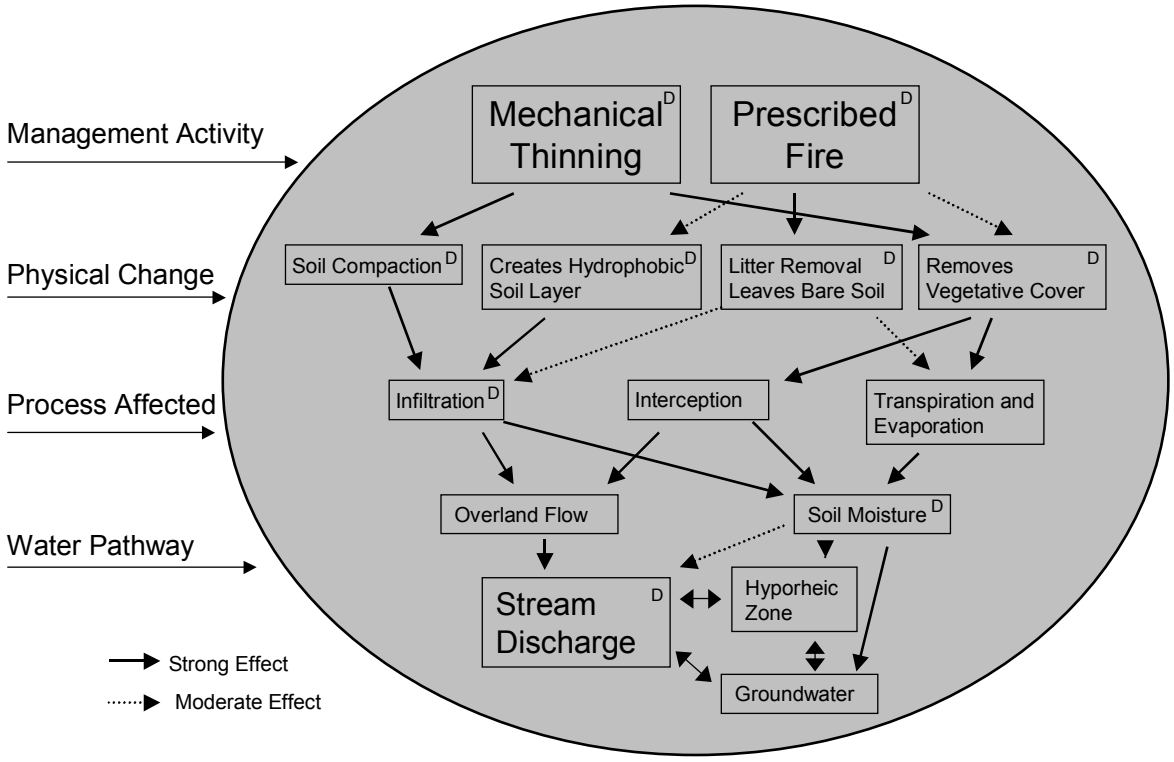


Figure 3.1. Stream discharge conceptual model for forest management effects on the Kings River Experimental Watershed. Meteorological processes govern the form and manner in which water enters and moves through the forest (see Section 2.2 for measurements). Attributes denoted by ^{D} will be measured directly.

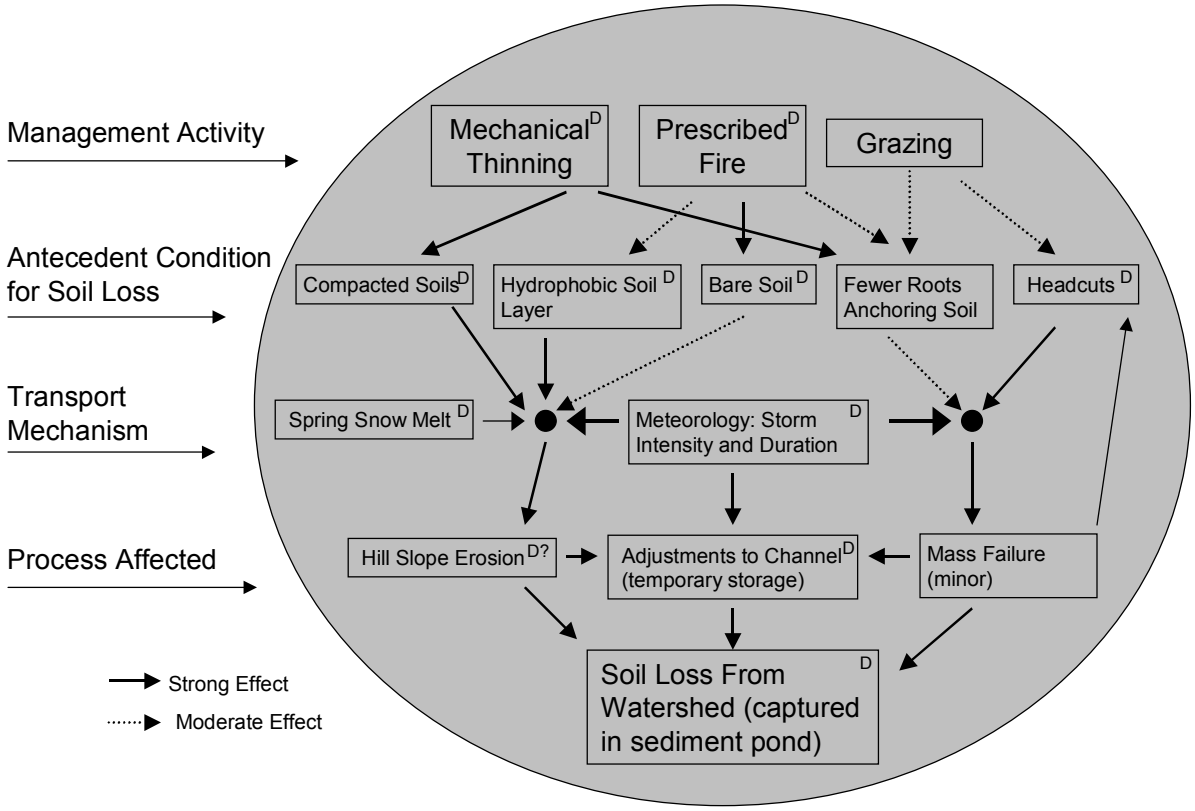


Figure 3.4. Soil loss conceptual model for forest management effects on the Kings River Experimental Watershed. Attributes denoted by ^{D} will be measured directly. At the black dots an antecedent condition and a transport mechanism combine to create erosion.

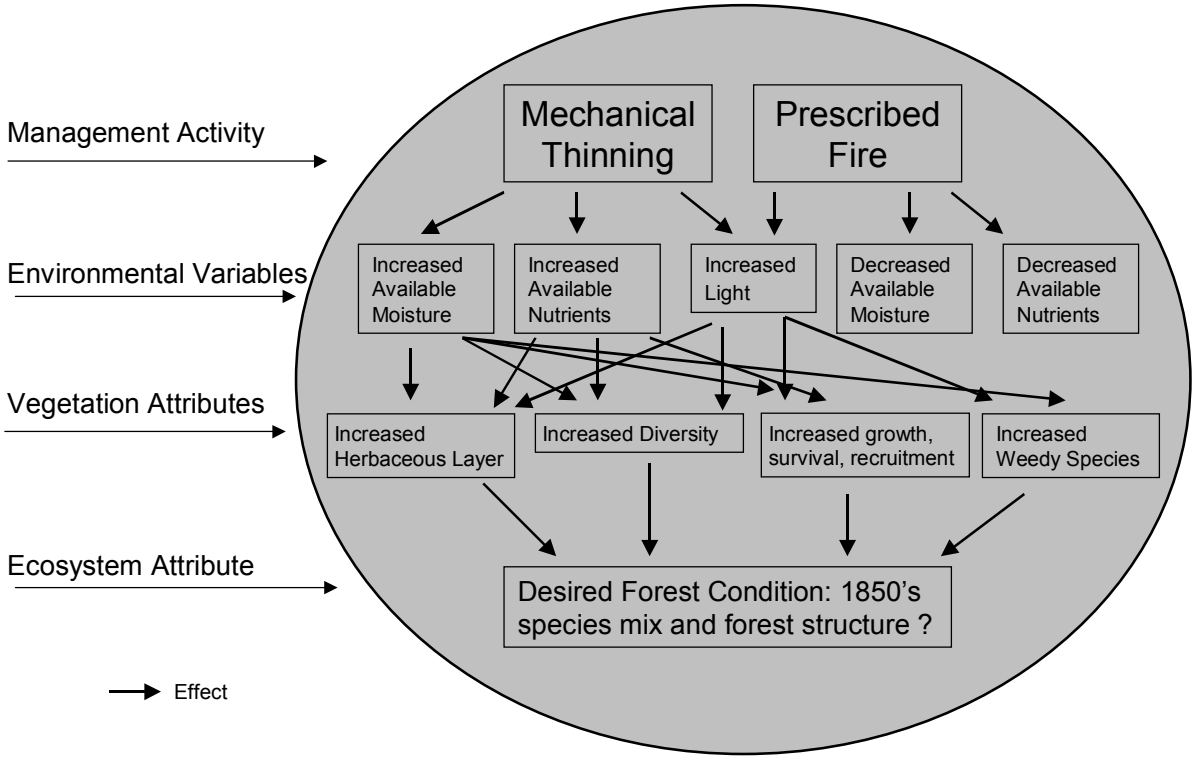


Figure 3.8. Vegetation conceptual model for forest management effects the season following treatment on the Kings River Experimental Watershed.

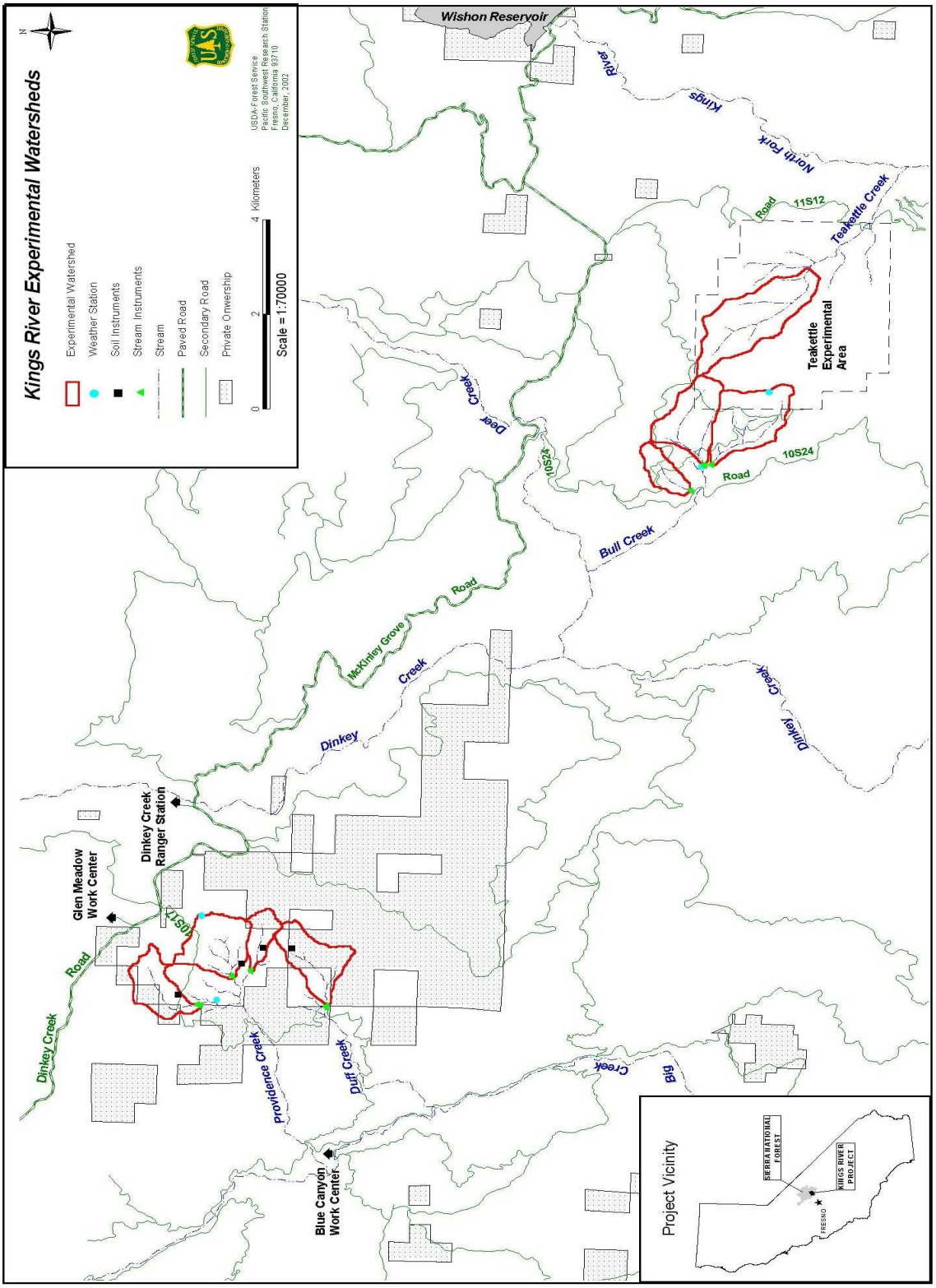


Figure 4.1-1. Kings River Experimental Study area within the Sierra National Forest of California. The study consists of eight headwater watersheds in the mixed-conifer forest type.

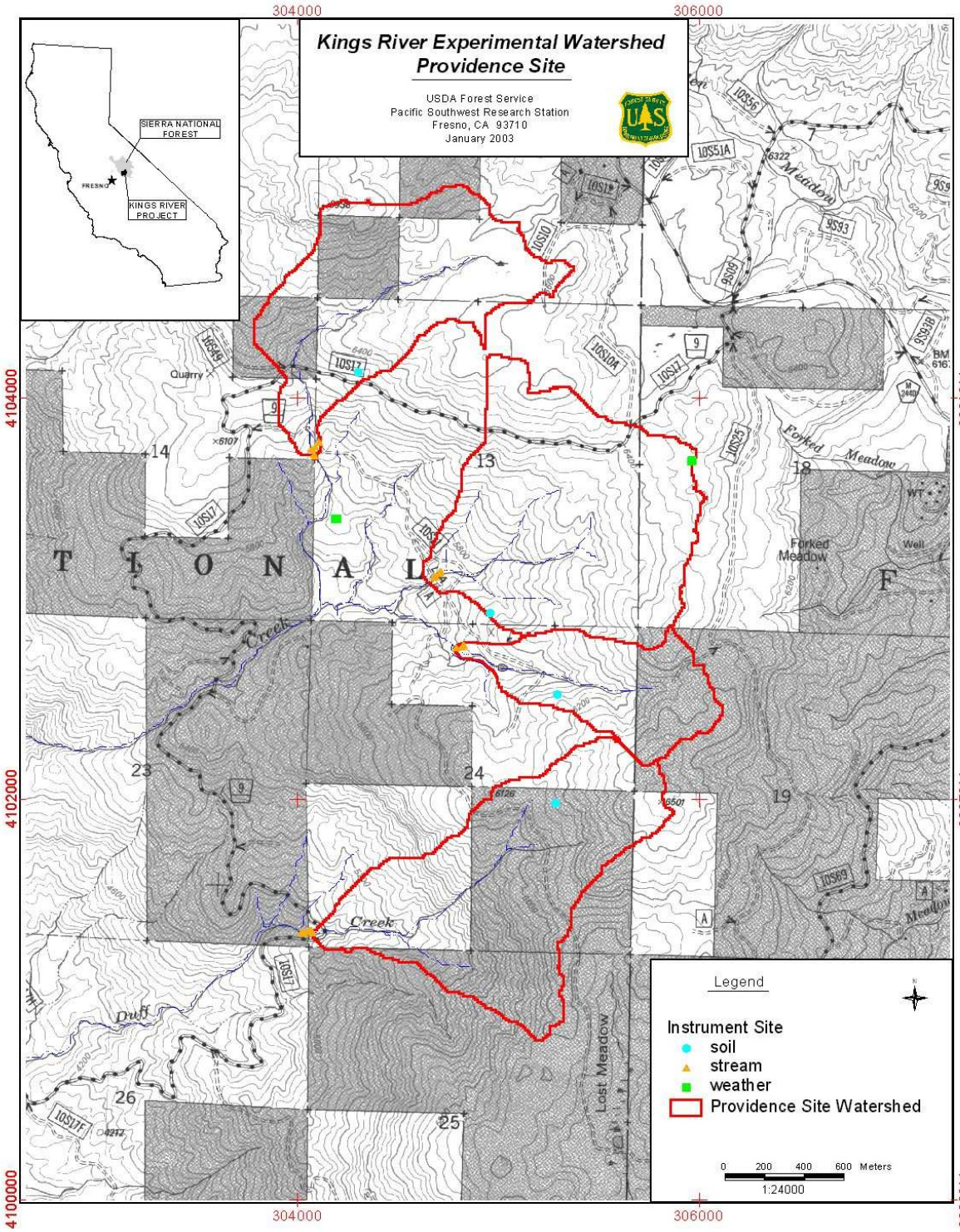


Figure 4.1-2. The locations of stream, soil, and weather instruments for the Providence Site are shown on this map. The Providence Site contains four watersheds : Providence 301 (P301), Providence 303 (P303), Providence 304 (P304), and Duff 102 (D102). Areas that are shaded in grey are private lands ; Southern California Edison owns these lands in P301 and D102.

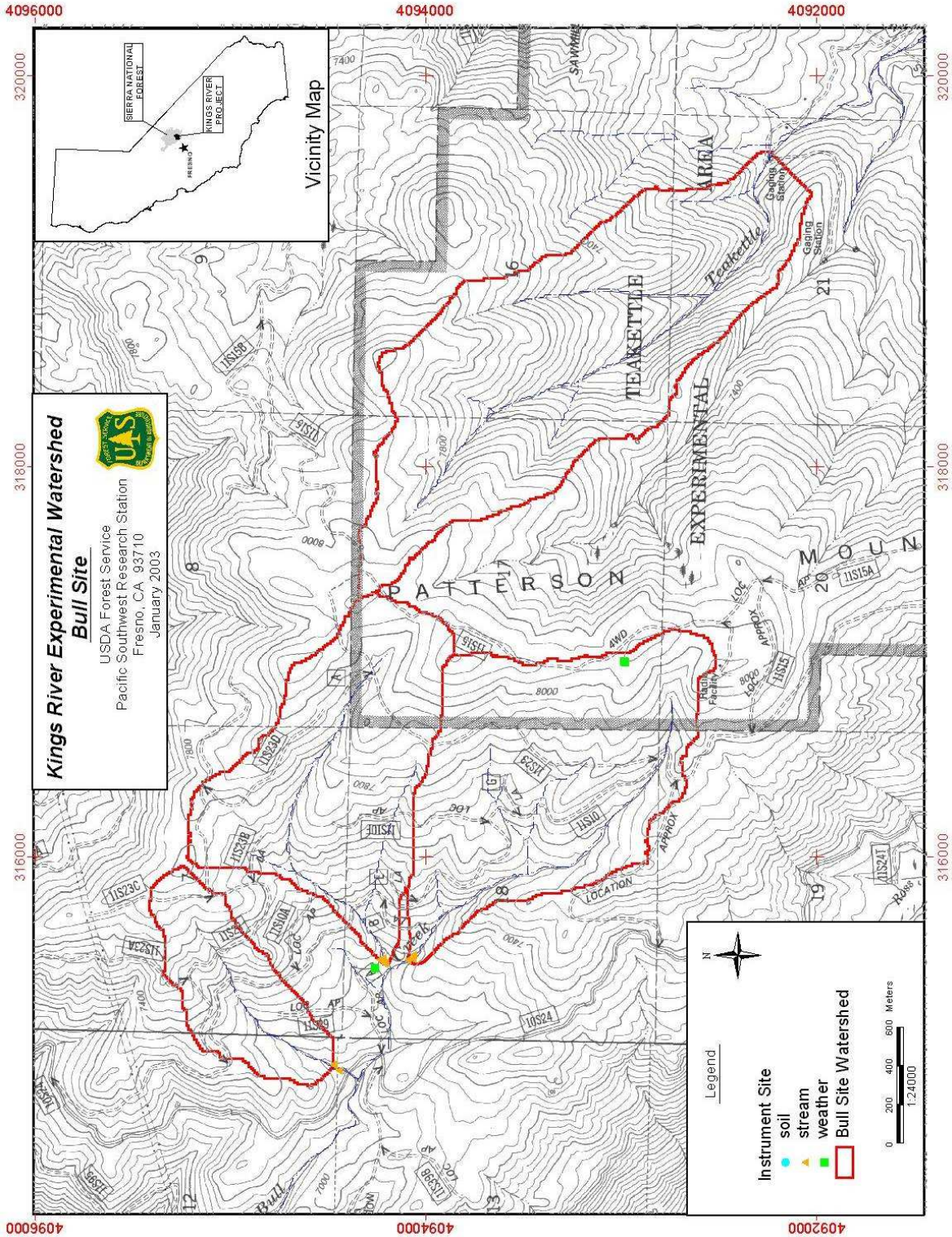


Figure 4.1-3. The locations of stream and weather instruments for the Bull Site are shown on this map. The Bull Site contains four watersheds: Bull 201 (B201), Bull 203 (B203), Bull 204 (B204), and Teakettle 1 (TK1). No privately owned land occurs in the Bull Site.

Figure 5.1-1. Two flumes installed on the Bull 201 stream; the view is looking downstream. The smaller flume in the foreground measures low summer discharge. The larger flume in the background measures peak discharges generated by large rain events.

Figure 5.1-2. Downloading data from the Aquarod during winter. The Aquarod provides a backup measurement of stream stage at 15-minute intervals from stilling wells on the large flumes. Aquarods are independent of the ISCO 730 bubbler, photovoltaic system, and the small flume.

Figure 5.2-1. Telemetry antenna near a meteorological tower location. These antennas will be used to transmit data over the Forest Service radio network to a computer in the Fresno office.

Figure 5.2-2. Meteorological tower showing from bottom to top: data logger control box, solar panel, temperature/relative humidity sensor, pyranometer, snow depth sensor, wind speed, and wind direction sensors.

Figure 5.2-3. Belfort gage, which measures liquid and frozen precipitation accurately. The top of the gauge has an Alter wind screen.

Figure 5.4. Sediment pond on the Providence 301 stream. The pond decreases the water velocity causing suspended sediment to drop out of the water column and be deposited in the pond. The accumulated sediment is removed and measured at the end of each water year.

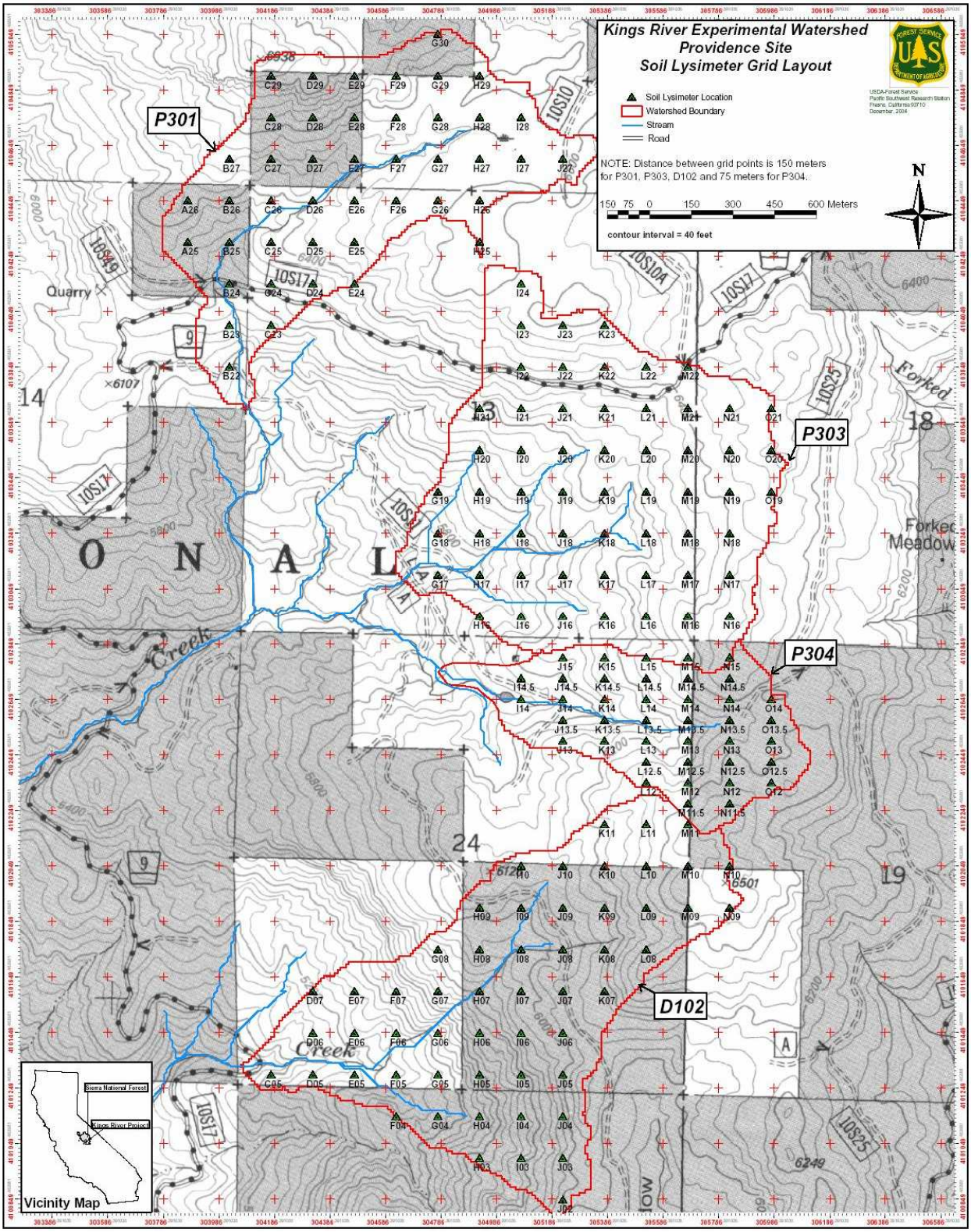


Figure 5.6-1. The watershed grid for the Providence Site. The grid has a uniform 150-m spacing, except for the smaller P304 watershed, which was densified to 75-m spacing in the north-south direction. This grid provides a sample framework for soil, vegetation, and fuels measurements.

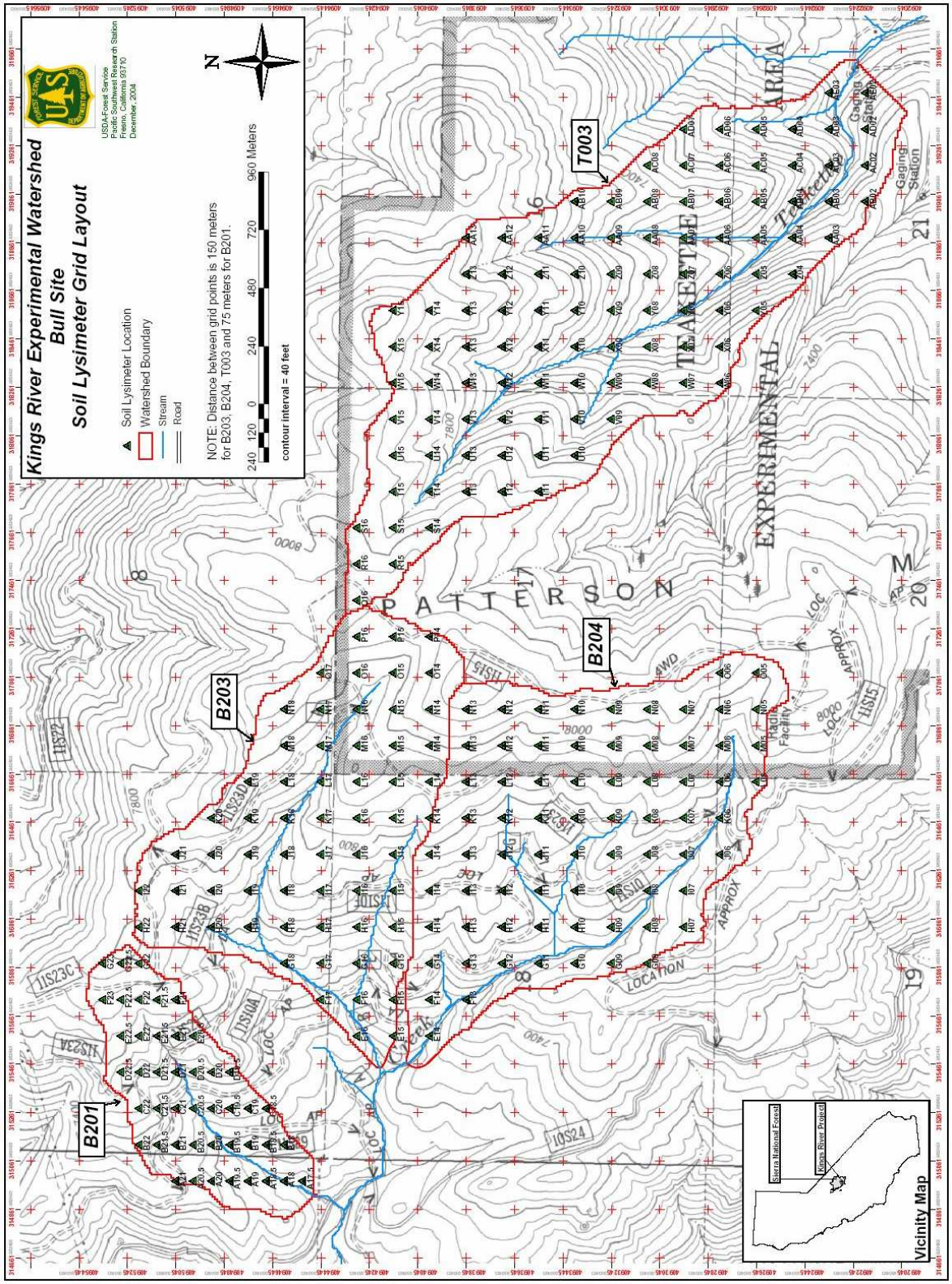
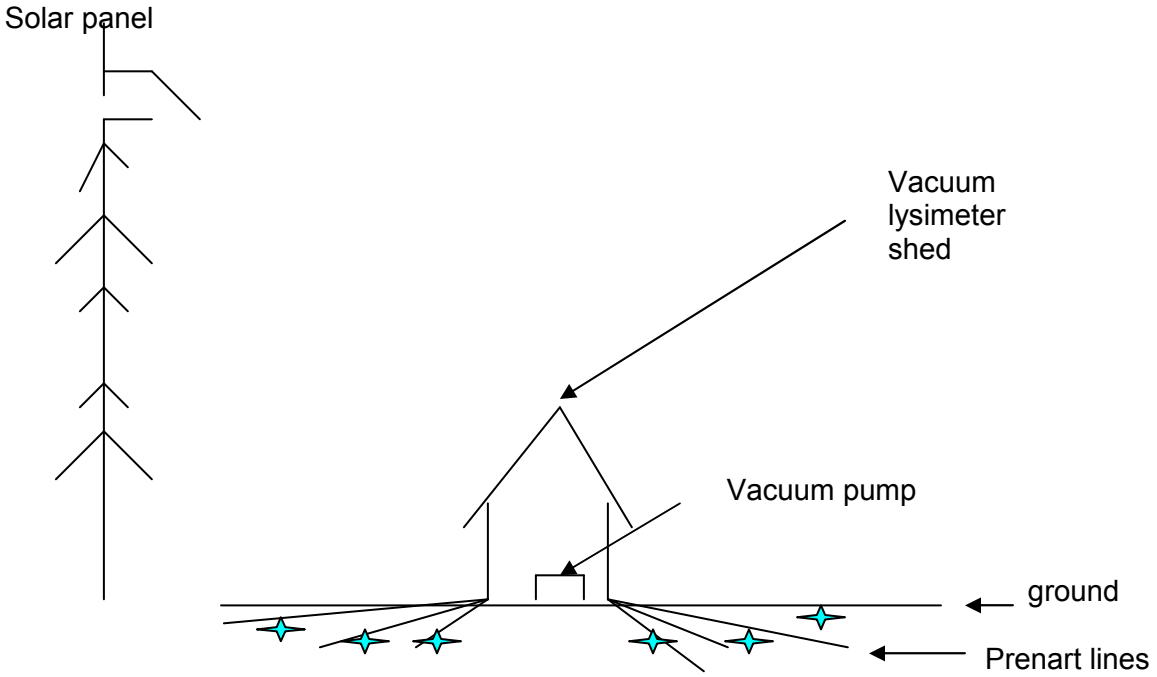
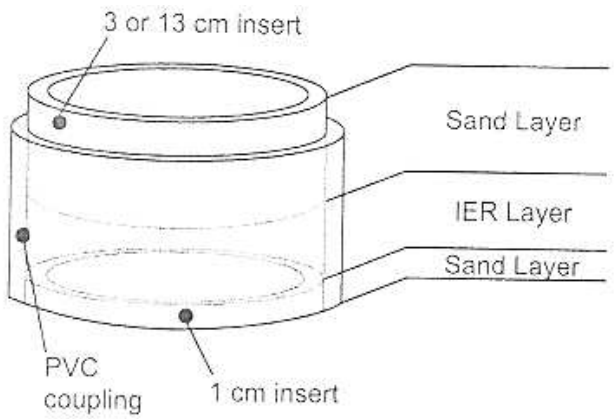


Figure 5.6-2. The watershed grid for the Bull Site. The grid has a uniform 150-m spacing, except the smaller B201 watershed, which was densified to 75-m spacing in the north-south direction. This grid provides a sample framework for soil, vegetation, and fuels measurements.



(a) Prenart System



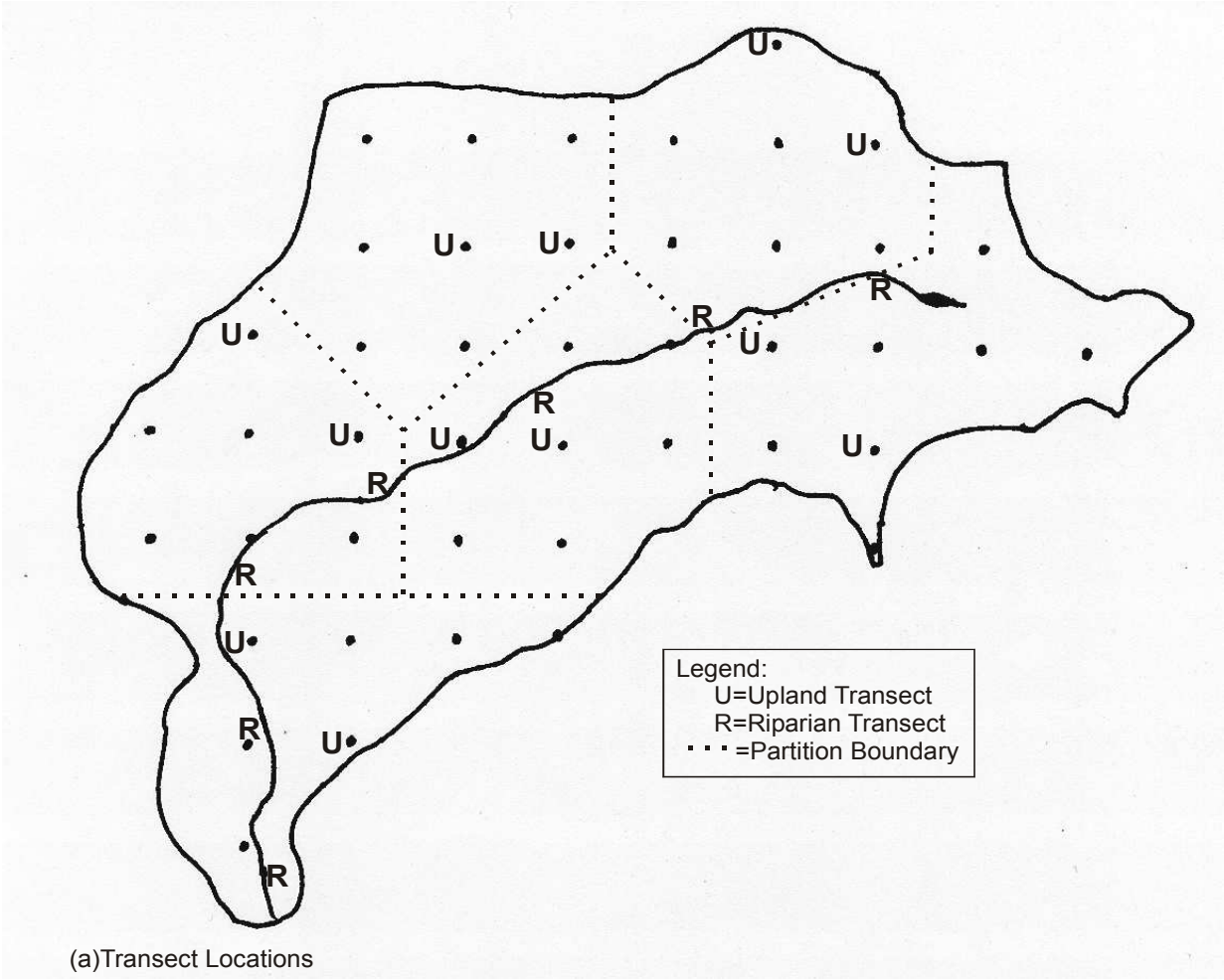
(b) Ion Exchange Resin Lysimeter

Figure 5.7-1. (a) Prenart vacuum lysimeter system showing the vacuum pump (housed in the shed) that draws soil water into bottles below the floor of the shed. Extending from either side of the shed is tubing leading from the vacuum pump to ceramic tips that extract the soil moisture. Six snowmelt collectors are placed about two meters down slope from the tips (indicated by the star symbols). Soil and throughfall resin lysimeters are co-located near the Prenart tips. The system is powered by a solar panel located in a nearby tree. (b) Ion Exchange Resin (IER) lysimeter for soil (Susfalk and Johnson, 2002). The IER lysimeters consist of 20 ml of resin beads between two layers of Nitex netting with sand on the top and bottom of the assembly. Soil lysimeters are 6 cm in length and throughfall lysimeters are 15 cm in length with tubing made from PVC pipe.

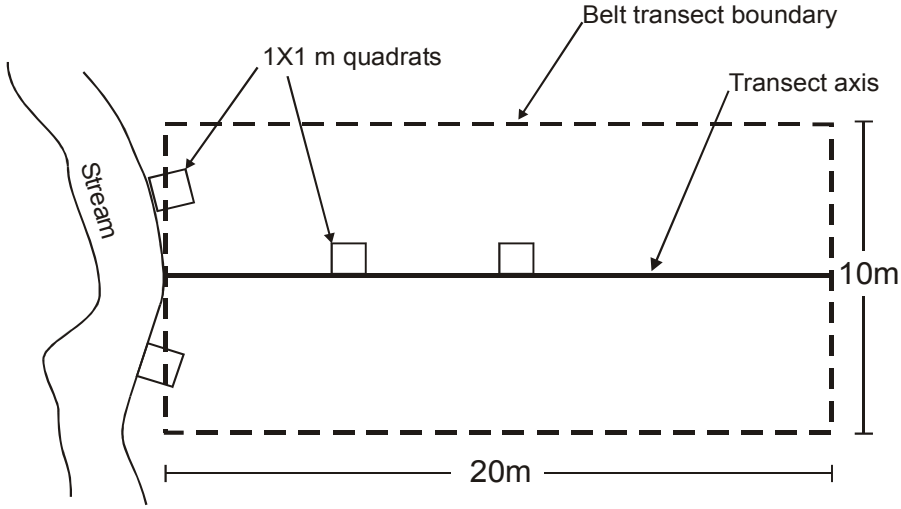
Figure 5.7-2. Snowmelt collector installation. Snow collects in the upper container, melts and drains into the lower container. A sample is collected by pumping water from the lower container into a collection bottle.

Figure 5.7-3. Complete snowmelt station showing snow collection bottle on the right and lines for sample collection and pump connection on the left.

Figure 5.7-4. Automated stream sampler apparatus. An ISCO 6712 sampler, housed in the shed, draws stream water up through the white pipe at intervals based on stream discharge or regular time-steps.



(a)Transect Locations



(b) Sample Transect

Figure 5.8. Aerial-view drawing of (a) the vegetation sampling design for the Providence 301 watershed, and (b) a sample riparian transect. Quadrats are located at 0, 5 & 10 m on the line; upland transects differ by having only one quadrat at 0 m, on the transect axis.