Jackson Demonstration State Forest

Research Plan

JDSF Research Committee
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Chapter 1. Introduction

Purpose

This Research Plan provides strategic guidance for research and demonstration activities in the Jackson Demonstration State Forest (JDSF). As discussed later in this document, it will be integrated with the JDSF Management Plan (Management Plan), refined and expanded as direction evolves within the context of the plan. Four Focus Areas are described and associated topics, priorities, and goals are developed to further research and demonstration projects by JDSF. This research plan is an addendum document to the Management Plan and will be reviewed on the same 5-year interval and updated every 10 years as part of the implementation of the Management Plan.

This research plan must be approved by the Director of CAL FIRE and the Board of Forestry and Fire Protection (Board).

Background and History

JDSF is the largest forest in the Demonstration State Forest system, which is managed by CAL FIRE as an actively managed, working forest on behalf of the public. Due to its size (48,652 acres) and location in the coast redwood region of California, it is a unique resource for conducting research on managed coastal forests in California. The Caspar Creek Experimental Watershed within the JDSF was designated as one of the national network of Long-term Ecological Research (LTER) sites.

Board policy and the Public Resources Code specify that the primary purpose of JDSF is to conduct innovative demonstrations, experiments, and education in forest management; that timber production will be the primary land use on JDSF, and that recreation is recognized as a secondary but compatible land use (Board Policy 0351.2). Relevant Board policies for Demonstration State Forests, including JDSF can be found in the Management Plan, Appendix I.

JDSF Research program functions are integrated with other programs on the Forest. Timber management activities complement research by creating desired stand structures, creating revenue for funding research, and addressing relevant research questions. In turn, research results support management decisions and can provide state of the art information not just for the Forest but throughout the redwood region. Monitoring can provide baseline data and when carefully collected over time can be considered research. Demonstrations and baseline data help support and inform research and management. Education and outreach utilize a science foundation to inform stakeholders and users. In addition to creating research opportunities regarding public use of JDSF, recreational use provides the State an opportunity to showcase forest management research to the public via casual encounter, guided trails, and roadside displays.

As a complementary document to the Management Plan, this research plan is the final product following years of input received from the Jackson Advisory Group (JAG), the Board's Research and Science Committee, technical experts (see Appendix 1), stakeholders and the general public. In January 2011 the JAG completed their recommendations for management of JDSF.

Their report addressed management direction for research and demonstration program planning, allocation of the landscape to different management regimes and forest condition goals, and governance of research and demonstration programs. The JAG however, felt that it was not qualified to develop a complete research plan and recognized that further adjustments to landscape allocations and desired future forest conditions would likely be necessary in order to develop the research plan. They recommended that this task be left for a future group to complete.

In July 2011 the Board took action on the JAG's recommendations and adopted the majority of them (see Appendix 2). The Board determined that the specifics of landscape allocations and silvicultural methods on JDSF should be finalized by its governance structure as part of the development of a research plan. In August, 2013, the Board adopted the JDSF Research Committee as its research governance structure for JDSF (see Appendix 3), and charged the Research Committee with developing the research plan.

The initial draft of this research plan was reviewed by a panel of former Board members who have served in the research community, Robert Heald, Gary Nakamura and Dr. Douglas Piirto. After their review and suggestions were incorporated, specified parts of this draft research plan were subjected to a rigorous review by an expert panel of professional scientists under the leadership of Dr. Richard Standiford at U.C. Berkeley (see Appendix 1). This plan incorporates the input from the expert panel, as well as input received from the JAG, the Board and the public during the final scoping process.

The expert panel identified the following as basic forest management requirements for this research plan:

- The management of JDSF should be no more restrictive than the regulations that govern forest practices in the region. The baseline for management should be the California Forest Practice Rules.

- The California Forest Practice Rules should be explicitly tested on JDSF. In order to test hypotheses and the validity of a given Rule, one may need to either go beyond the requirements of the Forest Practice Rules, or request a temporary exclusion (*i.e.,* less restrictive rule).

- Projects ideally should demonstrate existing and new methodology and technology (*e.g.,* silvicultural methods, logging systems, vegetation management, road designs, etc.).

- Maintain communication with researchers on any potential management actions in current study areas.

- Long-term stability in management, diverse stand structures/forest conditions, commitment to existing projects and opportunity for conducting research are key components for successful implementation of research projects on JDSF.

Chapter 2. Conceptual Framework

JDSF is unlike most of its neighbors. It is not a park or reserve in which limited management occurs and human influences on natural processes are minimized. Nor is it an industrial timber

holding, managed primarily for revenue generation. JDSF fills a unique niche as a managed, working research and demonstration forest.

Demonstration State Forests, including JDSF, are public lands that are mandated by law to provide opportunities to conduct research, demonstration, and education on sustainable forestry practices. Demonstration State Forests are required to balance periodic timber harvest with public trust resource values such as recreation, watershed protection, wildlife, range and forage, fisheries, and aesthetic enjoyment.

JDSF meets an important need to advance research and demonstration regarding sustainable forestry practices in a State with a large population that places high demands on forest lands for recreation, environmental protection and ecosystem services; yet these lands are also prized for agricultural and residential development. Given the often controversial role of timber production in California, JDSF needs to play an important role in helping maintain California's leadership as an innovator in creating solutions to difficult and contentious forest management issues.

The Forest's demonstration mission extends to helping develop science-based forest management tools. Research and demonstration clients specifically include scientists, foresters and other redwood natural resource professionals, forest landowners, and others with natural resource regulatory, policy and conservation interests. The partnership section includes a discussion of these groups (Chapter 7).

JDSF's unique role as a working public redwood forest provides the overarching demonstration of a sustainably managed 48,562 acre forest. Many of the management activities are directed towards creating a diversity of opportunities for future research and demonstration projects while some are integrated with specific projects. This plan identifies the need for varied stand structures, explicitly tying research goals more closely to management of the Forest. Research on the JDSF should help evaluate the short- and long-term effectiveness of prescribed treatments, environmental and ecological responses to specific management actions, and help inform forest management decisions throughout the redwood region and beyond. Applied and fundamental forest research has been conducted at JDSF for over fifty years furthering our understanding of managed forested ecosystems.

As an actively managed forest, JDSF provides operational experience, baseline data and infrastructure that are necessary to support a successful research program and foster future partnerships. In addition, the staff's local knowledge and experience enable a feasibility assessment on study plans which includes spatial conflict avoidance with ongoing or planned research projects. Staff support is flexible and ranges from providing basic site information to assistance with data collection and analysis.

JDSF continues to welcome research projects covering a wide range of subjects. This policy of welcoming all logistically viable research projects will be enhanced by the research planning process. All research proposed by universities, agencies and others with funding that has been secured by the researcher will be considered. Projects are subjected to review and only denied when they conflict with existing studies, legislation, or policies. Specific details for reviewing, funding, and implementing projects are addressed in Chapter 6, Administration and Funding.

Quantifying forest attribute changes over time is frequently required in natural resources research, but this creates practical limitations for studies that require multiple decades to complete. Studying a single site for multiple decades is often prohibitively expensive and difficult to accomplish. A successful strategy is to substitute space for time by ensuring that different stand ages and structures are present in otherwise similar forest areas. This plan will result in

creating a diverse range of forest and stand conditions to optimize the potential for as many different types of research as feasible.

Research and monitoring require extensive time and funding. In order to ensure that a wide variety of forest stand conditions are present throughout JDSF to facilitate future research, landscape allocations that are requisite for the focus areas are identified. These allocations also provide future opportunities for other projects. A variety of existing stand/forest conditions is necessary at any point in time to accommodate potential research projects. This necessity is driven by managing for long-term forest conditions (*e.g.,* snags, different age stands, etc.) as well as plan development processes associated with vegetation alterations that typically require multiple years (*i.e*., biological surveys, environmental review documents, etc.). JDSF's stable ownership and management is conducive to long-term research projects needed to understand complex forest issues.

Chapter 3. Focus Areas

This Research Plan is structured around four focus areas representing subject matter areas deemed to be of high interest and relevance to redwood forest management. These following four Focus Areas represent priority subject areas for CAL FIRE-funded research. However, all externally funded research projects will be encouraged with JDSF providing support as staff and funding are available and to the extent that the research objectives help achieve JDSF's primary objectives.

Focus Area Development Opportunities

Scale

Scale refers to the spatial component of research and management. Research questions are addressed at varying scales dependent upon the hypothesis, *e.g*., tree level, plot, stand level, watershed, landscape or regional. JDSF is over forty-eight thousand acres in the center of the redwood region and offers a gradient from coastal to interior redwood forest that provides a valuable opportunity for replicated research projects. However, it may be too small or may not have the appropriate attributes to function as the primary research site for some topics. Lands beyond JDSF each have their unique ecological attributes and management goals, whether private working forests or public parklands. Building partnerships that allow replication of research beyond JDSF is important. Because building partnerships takes time, initial Research Plan implementation is prioritized to occur on JDSF lands. Then, as implementation validates the Plan's approach, regional interest is expected to increase. The need to substitute space for time means that similar locations with different aged forests are needed to conduct studies in a realistic time frame.

Initial studies can be implemented with CAL FIRE and partner funding. JDSF will build on existing research infrastructure forest structure and partnerships while improving long-term research opportunities.

Context

The context idea refers to fostering research with relevance to managed forests like JDSF and prioritizing research within staffing and budget constraints. It recognizes that "customers" for JDSF research extend beyond the scientific community. Managers of redwood forests benefit

from public research that addresses issues regarding economic and environmental sustainability. Third-party research conducted on public land provides unrestricted data access which is an important component in facilitating public trust regarding forest management issues. This kind of research is also useful for informing public discussions of policy.

JDSF research and demonstration clients as well as the recreating public have open-access to the Forest; thereby increasing the opportunity to observe a variety of forest management methodologies first-hand.

Focus Area Concept

Although there are a multitude of possible forest and ecosystem management subject areas for research, the four broad "Focus Areas" below were identified as priority subject areas for CAL FIRE-funded research:

1. Sustainable forestry;
2. Watershed science, restoration and aquatic habitat recovery;
3. Upland terrestrial habitat and forest structural relationships;
4. Managed redwood forests' climate change adaptations and role in carbon sequestration.

Each of the following Focus Areas includes sections on current knowledge, research needs and themes and example projects. The brief sections on current knowledge, particularly as it relates to redwood forest management issues, helps identify research needs and themes for the Focus Area. Example projects are included, but are not intended as a comprehensive list for research at JDSF.

Focus Area 1 - Sustainable Forestry

The Sustainable Forestry Focus Area is intended to address fundamental questions about long-term management of redwood forests for timber and other ecosystem services. Understanding forest growth and yield dynamics whether viewed as timber, carbon, habitat or other parameters, is of broad interest. Silviculture in the coast redwood region is undergoing transition in response to social and ecological concerns. There are two interacting components of sustainable forestry: the first is better understanding of the biotic interactions, from clonal growth patterns to interactions of multiple species. The second includes further development and understanding of the forest management opportunities used to address these complex biological and economic interactions. At JDSF, the solid foundation of sustainable forestry research and demonstration provides a basis for future research.

Current Knowledge

JDSF's major silvicultural research contributions have been in thinning/stocking, redwood sprouting, and growth and yield. JDSF, and to a less extent Soquel DSF, have a unique role in redwood forest science because redwood is a very unique species with limited geographical distribution, and there is a dearth of research forests in the redwood region.

Due to the foundation provided by research on JDSF, the state of the knowledge of sustainable forestry is more advanced in this Focus Area than others. Nonetheless, new questions regularly arise and many unanswered questions remain. The interest in developing forests with continuous cover and multiple age classes creates new challenges as complex stand structures

with multiple layers or stratums are not well understood in the redwood region. Increased knowledge in the specific themes discussed below will assist in addressing new management challenges.

Thinning

The vast majority of the previous thinning research in coast redwood was conducted at JDSF. This includes the Whiskey Springs, Caspar Cutting Trials (Henry 1982, Lindquist 1999, 2004a, 2004b, Oliver *et al.* 1994) and a recent precommercial thinning study at Caspar Creek (O'Hara *et al.* 2014). Thinning, in all its various forms, remains the primary means of modifying stand structure and redirecting the trajectory of stand development. Recent studies have found very rapid occupation of growing space after regeneration, but much slower reoccupation after thinning (O'Hara *et al.* 2007, O'Hara and Berrill 2010). These findings have implications for structural development of redwood stands, the production of wood volume, and understory diversity.

Productivity, Growth and Yield

The early volume and yield table work for second-growth stands was completed cooperatively by the USDA FS, CDF, and UC Extension through UC Berkeley. This resulted in the early yield tables (Lindquist and Palley 1963). The developers of the CRYPTOS growth and yield model used permanent plot data on JDSF and other ownerships in the redwood region (Wensel *et al.* 1987). Whereas the growth model was derived primarily from even-aged stands, the CRYPTOS model, in its second generation form as FORSEE, is also used to project multiaged stands.

JDSF has also been a primary location for research in understanding site productivity relationships in coast redwood. Much of the early site index work with redwood and Douglas-fir took place at JDSF (*e.g.,* Wensel and Krumland 1986). More recent work at JDSF has attempted to develop new understandings of site quality evaluation in coast redwood (Berrill and O'Hara 2014).

Redwood Sprouting

The ability of redwoods to reproduce vegetatively is unique among commercial conifers. Prior research in the region, much of which was at JDSF (*e.g.,* Barrette 1966, Neal 1967, Cole 1983, and Lindquist 1979, 1989), has demonstrated the reliability of this source of regeneration as well as other regeneration methods (also see Wiant and Powers 1967, Powers and Wiant 1970). However, more recent research suggests that the light requirements for long-term survival of redwood sprouts that may not be met in some multiaged systems (O'Hara *et al.* 2007, O'Hara and Berrill 2010).

Regeneration Methods

Redwood forest regeneration has received less attention than other commercial forest types. The JDSF has been a source for research on regeneration methods in redwood – Douglas-fir stands. Even-aged regeneration was described by Jameson and Robards (2007). The ongoing Railroad Gulch study (Helms and Hipkin 1996) is testing the effects of group and single tree selection systems. Recent work that developed multiaged guidelines for mixed redwood – Douglas-fir stands was also largely completed at JDSF (Berrill and O'Hara 2007, 2009). There have been extraordinary changes in regeneration methods in the redwood region with an increasing emphasis on complex stand structures developed with multiaged silviculture. JDSF is well-positioned to lead the research in this area.

Fire and Disturbance Ecology

Redwoods are known for their resistance to fire and for the role fire plays in perpetuating redwood stands (Jacobs *et al.* 1985, Finney and Martin 1989, 1992, Finney 1993, Brown and Baxter 2003, Lorimer *et al.* 2009, Ramage *et al.* 2010). Brown and Baxter (2003) found fire frequency was greater near the coast at JDSF and Ramage *et al.* (2010) documented responses of redwood and tanoak to the 2008 fires at JDSF and other sites. The emerging threat of sudden oak death (SOD) (*Phytophthera ramorum*) is critical to management of redwood forests including those at JDSF. Previous work has looked at changes in stand development patterns (Waring and O'Hara 2008, Ramage and O'Hara 2010, Ramage *et al.* 2011), effects on fuels, and other management strategies (Valachovic *et al.* 2011).

Old Forest Ecology and Management

Coast redwood old forest ecosystems have been the subject of considerable research, but less study than more extensive western forest types such as coast Douglas-fir or ponderosa pine. Stone and Vasey (1968) documented impacts of flooding on old growth redwood forests on alluvial flats. Fujimori (1977, Fujimori *et al.* 1976) studied redwood forest productivity in old redwood forests. Other work has documented amounts of coarse wood debris (Bingham and Sawyer 1988), gap dynamics (Sugihara 1996, Hunter *et al.* 1999), edge effects (Russell and Jones 2001), and fog use by redwoods (Dawson 1998). More recently the work of Sillett and others (*e.g.,* Sillett and Van Pelt 2000, 2007, Sillett *et al.* 2010) studied the complexity and biological diversity in tree crowns, and higher rates of individual tree increment in older redwood trees. Other old forest research is described in Noss (2000). A number of recent studies have looked at restoration of old redwood forests in the north coast area. Most of these have attempted to alter the developmental trajectory of younger stands towards old forest structures (O'Hara *et al.* 2010, 2012). These studies have demonstrated that growth rates can be increased, species compositions altered, and the development of more complex structures can be initiated with management.

Research Needs and Themes

Regeneration Methods

JDSF was established for the purpose of researching second growth forests. Among the primary concerns was the potential for reduced wood quality. The major shifts from even-aged to multiaged silviculture also have the potential to affect wood properties. Management at JDSF can serve as the source of material for examining wood properties from different stand structures.

JDSF can be the center for researching and demonstrating alternative regeneration methods in the redwood region. These include the full range of methods from complex multiaged stands to even-aged stands. There should be examples of retention systems that include variable numbers of reserve trees from very few to many. There can also be demonstrations of tradeoffs associated with retaining these trees through full rotations or partial rotations. Multiaged stands are becoming more common in the redwood region, yet there are many gaps in knowledge regarding the stability of these systems, their yield, or effects on wildlife habitat. JDSF can have a network of these regeneration system examples, with and without artificial regeneration, to allow future study in multi-aged stands. New practices such as the irregular shelterwood, or Femelschlag (O'Hara, 2014), and other alternative approaches should be demonstrated at JDSF.

The recent utilization of only uneven-aged silviculture in the matrix area of the Forest has had the effect of limiting opportunities to research and demonstrate a range of silvicultural methods

and resulting stand structures. The Management Plan and JAG report direction remains quite limiting. The most widely used even-aged regeneration method in the redwood region, clearcutting, is generally limited in the JDSF to 100 acres per decade. The remaining possible 2,600 acres of even-aged harvests per decade could be used for traditional or alternate silviculture demonstrations and experiments. The desired future condition lists 10 to 20% of the forest structure as regeneration and pole-sized trees (see Chapter 4). Both these numerical benchmarks reflect the larger Management Plan objectives and are still less than optimum for creating a diverse range of research and demonstration forest structures and age classes. However, at least by returning to the 2008 Management Plan direction, the Forest will resume creating some even-aged stands across the site spectrum of JDSF including coastal and inland sites, with different species compositions, at different densities, and with a range of intermediate treatment histories.

Thinning

Thinning treatments reduce the density of trees in stands of any structure. These treatments result in increased residual tree growth and possibly increased merchantable volume production. They also increase residual tree vigor and allow changes in the trajectory of stand development to affect wildlife habitat, aesthetics, hydrologic functions and more. Interpreting thinning study results is complicated by different types of measures (net vs. gross vs. merchantable response), including thinned tree volumes in calculations, and whether to include mortality. Thinning studies in simple structures, such as even-aged stands, eliminate additional variables that might complicate results. However, understanding thinning responses in multiaged stands is important to determine if results from even-aged stands can be extended to more complex stand structures. Thinning studies in both even-aged and multiaged stand structures are therefore needed to understand the effects of these important treatments.

Productivity, Growth and Yield

To help answer questions in novel and traditional stands, JDSF will continue to maintain current permanent study plots and work towards establishing new plots to monitor the development of both single age and multiaged stands.

Questions regarding productivity through both time and a range of forest locations can be addressed utilizing the long-term inventory plots known as Continuous Forest Inventory (CFI) plots. CFI plot remeasurement will continue and, as staffing and budget allows, expanded to encompass a greater network of plots to monitor general changes in productivity associated with management, as well as measuring indicators of a changing climate.

Old Forest Development Areas

The Management Plan describes an effort to increase the acreage of older forests on JDSF; this is a sound strategy. Increasing the amount of old forest areas will be achieved by encouraging development of mature stands near existing old forests. There is also a need to disperse these areas across JDSF to include coastal and inland sites, and sites on different types of topography. There are numerous potential questions that could be examined in these areas as well as stand treatments that could be implemented to encourage, or accelerate development of old forest characteristics. For example, wider spacing to accelerate old forest characteristics (O'Hara *et al.* 2010, 2012), reconstructing growth rates of large trees (*e.g.,* Latham and Tappeiner 2002), treatments to stimulate tree stem hollows (goose pens), or treatments to develop reiterated stems (*e.g.,* Sillett and Van Pelt 2007) could be expanded.

Forest Operations

Forest Operations includes both technical and regulatory topics relevant to lands managed for sustainable forestry including: harvesting technology, Forest Practice Rules, and herbicide use. Harvesting technologies continue to evolve. Demonstrating these technologies as well as researching tradeoffs between different types of logging systems, road designs, and road decommissioning should be an important component of future projects on JDSF. Technologies for commercial and precommercial thinning, such as methodologies to yard and process small trees, could also be tested.

California's Forest Practice Rules should be explicitly tested at JDSF. This type of testing could require exemptions from the Forest Practice regulations so that the full range of treatments and effects can be measured. These might include research and demonstrations of sound management practices, but also the determination of the effects of less restrictive practices to help determine the validity of current rules. Specific research projects may not always be able to address emerging issues, but a library of stand management techniques and supporting data will lead to an increased understanding of regulatory implications.

Herbicides are commonly used in redwood forest management. Herbicides may not have widespread public acceptance as a tool for forest management, highlighting the need to test them under conditions where their long-term effects can be studied. JDSF should be a testing site for the judicious use of these chemicals. Ideally the use of herbicides, or any forest management practices, should be no more restricted on a research and demonstration forest than on similar forests in general. The Management Plan addressed social concerns by specifying that operational herbicide use for invasive weed management (IWM) is part of an integrated program that also uses prevention, manual control and other techniques. Invasive species from woody plants to pathogens are present on both JDSF and throughout the redwood region. The SOD occurrence on JDSF presents an opportunity to investigate management techniques that may lead to control of this pathogen.

Fire and Disturbance Ecology

Fire is an important disturbance agent on JDSF as evident from the 2008 Indian Springs fire. Wind, insects and pathogens are other important disturbance mechanisms as are invasive species, such as Sudden Oak Disease (SOD). These disturbances change forest structure, create gaps (*e.g.,* Sugihara 1986), and may result in development of new age classes of trees. Inasmuch as contemporary silviculture and forest management emulate natural disturbance patterns on some ownerships, understanding these disturbance patterns is important for future management.

Potential climate change adaption strategies can be demonstrated for managed forests at JDSF. These strategies might include trials of more southern provenances (seed zones) of redwood and Douglas-fir in both even-aged and multiaged stands. Alternatively, demonstrating alternative stand structures that are more resistant to a warmer and dryer climate could be studied. These could include structures that may be more appropriate in the southern part of the range, but which can be demonstrated at JDSF. JDSF's east-west gradient of localized climate may provide an opportunity to test other assumptions regarding species adaptability.

Redwood Genetics and Clonal Pattern

Studies of clonal patterns in redwood have revealed limited spread of clones in both old and second-growth forests (Rodgers 2000, Douhovnikoff *et al.* 2004, Narayan in prep). These studies have implications for the use of clones in redwood reforestation. Active exploration of deployment strategies for redwood clones should be tested.

Example Projects

- Inform the State Forest Practice regulatory process. The Board develops forest practice rules to address emerging forest management problems, and to refine existing rules that have been found to be insufficient or too restrictive. Specific research projects may not always be able to address emerging issues, but a library of stand management techniques and supporting data will help inform the Board. An example of a researchable question is the appropriate stocking standards for redwood.

- Hardwood and conifer interactions: specifically investigate the relationships between tanoak stump sprouts and adjacent redwood seedling growth.

- Are there useful measures of inherent site productivity that can be derived from abiotic (topography and soils) or biotic (indicator shrub or understory) variables?

- Timber harvesting and economics: More complex stand structures are not as well understood with respect to long-term sustained productivity. Sustainable harvests levels are predicated on sufficient stocking and an understanding of the inherent site productivity. Economic analyses can be informed by a library of forest management techniques and outcomes.

Forest Conditions and Scale

Sustainable Forestry research can encompass multiple scales, ranging from individual stands to management units or entire watersheds. Many research studies will require space for fixed area plots, buffers around plots, and replications within stands or in different stands. Long-term studies may require particularly large plots that, for example, allow trees to reach large size while maintaining a sufficient sample size. Large contiguous stands and multiple stands on similar sites and at similar stages of development may be needed to accommodate these types of studies. To facilitate individual plot replication on typical forest sites, long-term plot installations may require up to 20-30 acres. Replication will be needed to assess slope, aspect, and topographic position as well as a coastal to interior gradient. Research oriented towards multi-stratum stands or hardwood dynamics on JDSF will require more extensive sampling than those conducted in homogenous single stratum stands. Small watersheds can be a useful unit for providing replication across varied gradients and aspects. Arranging a chronosequence of similar treatments in a compact area such as a management unit can allow the substitution of space for time for silviculture and other studies.

Focus Area 2 - Watershed Science, Restoration and Aquatic Habitat Recovery

Watershed Science, Restoration and Aquatic Habitat Recovery recognizes the importance of improving our understanding of watershed processes and aquatic habitats, particularly for coast redwood forests. The existing Caspar Creek watershed study has provided a key foundation for this Focus Area, but there are opportunities for additional plot- and process-based studies in the Caspar Creek watersheds as well as in the other portions of JDSF. Past examples of plot and process studies conducted in the Caspar Creek Experimental Watersheds include: Reid *et al.* (2010), Dewey (2007), Barrett *et al.* (2012), Bawcom (2007), Keppeler and Brown (1998), Keppeler *et al.* (1994), Reid and Keppeler (2012), Reid and Lewis (2007); Ziemer and Albright (1987), Albright (1992), Reid and Hilton (1998), and Rice (1996).

Current Knowledge

JDSF has played a critical role in understanding the effects of forest management on runoff and sediment yields in the coast redwood region, primarily through the intensive monitoring and research conducted on the Caspar Creek watershed. This is a joint project between CAL FIRE and the USDA Forest Service Pacific Southwest (PSW) Research Station, and its 50-year record is unique in in the redwood region. While there are numerous other monitored watersheds in the redwood region (Harris *et al.* 2007), these generally are either managed (without controls) or controls (defined here as unmanaged) without any closely-paired managed counterpart. The managed watersheds outside of JDSF are effectively uncontrolled experiments, and the data have been used to identify the effects of forest management on turbidity and sediment yields (Klein *et al.* 2012, Sullivan *et al.* 2012, Lewis 2013). The problem is that these watersheds are generally under continuous management, so it is difficult to clearly identify the underlying causal processes and the specific management changes that would be needed to minimize future adverse impacts. The very limited number of unmanaged controls or reference watersheds (*e.g.*, Little Lost Man, Prairie Creek, and the Little South Fork of the Elk River) are crucial for providing baseline information and data on natural variability. These types of watersheds should not be used for experimental treatments, and cannot be easily paired with specific managed watersheds. This means that the Caspar Creek watersheds, with both managed and control basins, represent a unique resource for replicated and/or nested watershed-scale experiments in the redwood region.

The extensive body of work for the Caspar Creek experimental watersheds was summarized by Cafferata and Reid (2013), including two major watershed-scale experiments conducted in the South Fork and North Fork watersheds. Topics addressed included: peak flows, summer low flows, annual water yield changes, hillslope hydrology impacts, fog drip, sediment yields, surface erosion, channel erosion, stream temperature, nutrient cycling, large wood input, biological changes, and cumulative watershed effects.

The studies on the changes in peak flows and low flows appear to be the most useful and currently applicable, as these are largely driven by the change in canopy cover and only secondarily by the specific forest practices used at that time. The changes in erosion, sediment yields, and temperature are less directly applicable because of the substantial changes in management practices since 1992, when the North Fork harvesting was completed. A study plan for a third watershed experiment in the South Fork will be completed in 2015, and possible topics for research there, or possibly elsewhere on JDSF, are identified in the following sections.

Research Needs and Themes

Hillslope Sediment Production, Sediment Storage, and Sediment Delivery

The North Coast of California has some of the highest sediment yields in the world due to the high uplift rates, high rainfall, and particularly weak geologic units (Andrews and Antweiler 2013). The generally fine-textured geologic materials found in this region means that these high sediment yields also cause high turbidity levels. This is a major concern because of the potential adverse effects on the anadromous salmonid populations, many of which have been declared threatened or endangered by state and federal agencies. Most of the large watersheds in the northern part of the California Coast Ranges have been listed as sediment impaired under Section 303(d) of the Clean Water Act. This has resulted in the development of sediment TMDLs (Total Maximum Daily Loads), but the development of sediment TMDLs is hindered by the lack of accurate sediment budgets. A better understanding of both legacy and recent

human-induced increases in turbidity and sediment yields can inform watershed-scale assessments and water quality regulations.

The effect of management activities and the current record of instream sediment monitoring also needs to be put into a longer-term context. Long-term denudation rates can be estimated by using beryllium-10, a naturally occurring cosmogenic isotope. Published data for four headwater and two mainstem locations in the Caspar Creek watersheds (Ferrier *et al.* 2005, Balco *et al.* 2013) generally indicate that measured sediment yields are substantially less than the mean long-term (~3000-8000 year) denudation rates derived from the beryllium-10 data. Klein *et al.* (2012) found that turbidities in the mid-2000s were most closely related to a calculated management index for 1990-95 based on canopy removal (Equivalent Clearcut Area, or ECA), and that watersheds that had not been recently harvested were still exhibiting legacy effects.

These results indicate a clear need to develop more accurate sediment budgets, with particular attention to: (1) soil creep rates; (2) the current amount of stored sediment due to both recent and legacy land management practices (Koehler *et al.* 2001); (3) how much stored sediment is likely to be exhumed versus remaining in long-term storage; and (4) quantification of sediment from current management practices under the California Forest Practice Rules. The statistical analyses of multiple watersheds has been a useful first step, but this needs to be followed with more detailed, process-based studies to better understand and separate the relative effects of geology, different erosion processes, and current forest management on turbidity and sediment yields.

Cumulative Watershed Effects

A related topic is the need to clarify and quantify cumulative watershed effects (CWEs). While the North Fork Caspar Creek experiment was designed to quantify the cumulative watershed effects of clearcutting on sediment and peak flows (Lewis *et al.* 2001), much remains to be learned regarding this topic. CWE assessment has long been problematic (*e.g.*, MacDonald 2000, Reid 2010). California's Forest Practice Rules require CWEs to be addressed in Timber Harvesting Plans, but this is primarily a checklist and qualitative assessment. Increasingly sophisticated GIS databases and models provide a much greater opportunity to develop and test different models and disturbance indices that could provide a more rigorous assessment of past, present, and future cumulative watershed effects (*e.g.,* TerrainWorks (NetMaps); *http://www.terrainworks.com/*). More focused procedures can help identify the cumulative effect of specific sources and help identify potential problems, such as the GIS-based analysis of road networks (GRAIP; http://www.fs.fed.us/GRAIP/). GIS-based tools to identify potentially unstable areas such as SHALSTAB (W. Dietrich, *et al*. 2001) or SINMAP (Tarolli and Tarboton 2006) have already proved valuable, but these each only address one primary sediment source or process.

The long-term data set, nested design, and relatively large number of gaged watersheds in the South Fork of Caspar Creek will provide a unique opportunity to investigate both the prediction of cumulative watershed effects and associated key interactions. This includes the potential for developing, testing, and possibly validating improved procedures for evaluating the relative likelihood of different types of cumulative watershed effects. This could include developing and testing a series of disturbance indices with different weightings that can be used to represent different issues of concern. For example, the canopy derived weightings currently used by the North Coast Regional Water Quality Control Board (NCRWQCB) only represent canopy removal (*e.g*., roads are weighted the same as clearcuts). This set of weightings is not valid for the generation of infiltration-excess (Horton) overland flow, surface erosion, or management-induced mass movements. Different sets of weightings need to be developed based on

process-based studies, and these then need to be tested against watershed-scale measurements to determine what set(s) of disturbance indices best represent the observed watershed responses and are most appropriate for a given resource or concern.

Water Temperature

Water temperature increases associated with timber harvesting are another major concern in much of the redwood region because high temperatures can be a limiting factor for salmonids. Relative to sediment, there is a much better knowledge of stream temperatures and the radiation balance of streams (Moore *et al.* 2005). This understanding has been incorporated into physically-based models to quantify how forest management can affect the inputs and outputs of shortwave and longwave radiation and hence stream temperatures (*e.g.*, Boyd 1996, Allen 2008). A simple model was tested in the North Fork of Caspar Creek in the late 1980's (Cafferata and Reid 2013). What is lacking is a better understanding of the other controls on stream water temperatures, such as the amount of hyporheic exchange and groundwater inputs. While these factors are much more complex to quantify, high quality topographic and geologic data offer the potential to quantify both larger scale factors such as stream sinuosity and valley bottom width, and smaller scale factors such as point bars. These data may then allow a better prediction of stream temperatures and the relative sensitivity of different streams to temperature increases by affecting the amount of hyporheic exchange relative to streamflow and groundwater storage.

Canopy requirements for headwater streams continue to be debated during implementation of recently adopted Forest Practice Rules for non-fish bearing streams. Janisch *et al.* (2012) reported that very small headwater streams may be fundamentally different than larger watercourses, and that factors other than shade from overstory tree canopy appear to be critical for predicting water temperature changes. A greater understanding of the factors affecting headwater stream temperatures is well suited for study at Caspar Creek or elsewhere on JDSF.

Major advantages of temperature studies relative to sediment or hydrology are that water temperatures are relatively inexpensive and easy to monitor, rapid and direct responses to management can be expected, and the interannual variability is not as large or skewed. Hence more definitive results can be obtained in a three-to-five year funding window.

Watershed Restoration

Watershed restoration has received considerable attention and funding, but most watershed restoration projects do not result in publishable results that can then be used to guide future projects. Usually there is not sufficient pre- and post-project monitoring data to rigorously evaluate whether the project succeeded and why, and in many cases this problem is compounded by a lack of explicit, specific objectives that would help define the primary monitoring needs and the criteria for success.

JDSF can be used for rigorous case studies of site-specific riparian manipulation and aquatic habitat restoration projects. Sites in JDSF and the Caspar Creek experimental watersheds could allow for manipulative testing of the effect of certain key factors, such as the amount of large woody debris (LWD) on fish populations and aquatic food webs, or a study analogous to the riparian canopy experiment being conducted by Green Diamond Resource Company. Data documenting whether creation of red alder patches, gaps, or thinned riparian zones along fish-bearing streams improve aquatic productivity and fish biomass (particularly in the zone of coastal influence) are needed throughout the northern part of the Coast Ranges (Wilzbach *et al.* 2005). Alternatively, the lower part of the Caspar Creek watershed can be used as the basis for

comparison for manipulative studies in other watersheds, such as the addition of large amounts of large woody debris throughout the nearby Pudding Creek watershed (Gallagher *et al.* 2012).

Example Projects

- Include additional plot- and process-based studies in the next Caspar Creek experiment (*e.g.*, hillslope sediment production and delivery, headwater channel incision, instream sediment storage) to improve sediment budgets.

- Compare sediment production from legacy sources with and without watershed rehabilitation in the Caspar Creek watersheds (*e.g.,* road decommissioning undertaken with timber harvest).

- Implement rigorous case studies of site-specific riparian manipulation and aquatic habitat restoration projects.

Forest Conditions and Scale

Watershed research on JDSF should continue and strengthen the integration of plot and process studies with watershed scale measurements, as these are mutually reinforcing (Figure 1). More specifically, plot and process studies are needed to interpret watershed-scale results, and to provide specific management recommendations. Plot, process and watershed-scale measurements are also needed to develop, test, and validate models (Figure 1), and models are often the only means to extrapolate the results to other sites or conditions.

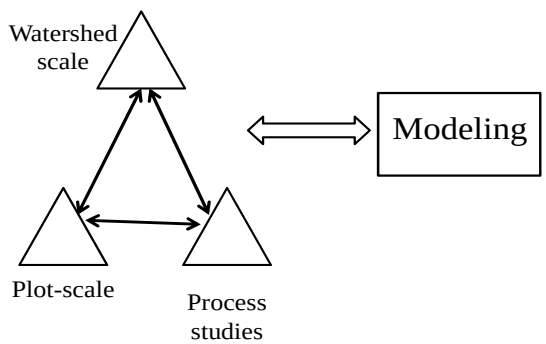

Figure 1. Conceptual view of how different types and scales of studies are needed for an integrated understanding of watershed response and to guide models and management.

Watershed research benefits strongly from having untreated control watersheds to make comparisons to treated watersheds. As stated above, they are regionally rare and valuable for providing baseline conditions. The paired watershed approach has been the cornerstone of research on how forest management affects runoff, sediment yields, nutrient outputs, etc. For maximum rigor and sensitivity, the paired watershed requires the establishment of a pretreatment relationship between a control and a to-be-treated watershed ("calibration period). One of the watersheds is treated, and then the change in the relationship defines the treatment effect (Wilm, 1949). This approach has been utilized in both of the main experiments conducted in the Caspar Creek watershed. Control does not denote pristine conditions, such as occurs at reference watersheds without anthropogenic impacts. All of JDSF's watersheds have been subjected to old-growth logging so they cannot be considered pristine, but this does not obviate their value as unmanaged controls. In the case of the Caspar Creek watersheds, control sub-watersheds H, I, and M in the North Fork need to be kept as unmanaged controls for the

projected 100-year duration of the Caspar Creek watershed study. The long-term design of this study is documented in a 100-year Memorandum of Understanding that is jointly reviewed and signed by the USFS PSW and CAL FIRE every five years.

Focus Area 3 - Upland Terrestrial Habitat and Forest Structural Relationships

The Upland Terrestrial Habitat and Forest Structure Relationships Focus Area recognizes that forests function ecologically by providing habitat for wildlife and other organisms and conversely, that wildlife play a role in forest function. Redwood forest lands have experienced major changes in the last 200 years, yet they continue to provide habitat for many species. Conserving legacy forest habitat is a well-established practice. Understanding when and how these managed forests can provide habitat is the key question for this Focus Area.

Current Knowledge

Coastal redwood forests host a suite of sensitive terrestrial vertebrates. Due to the focus on single-species conservation at the state and federal level, most wildlife research in the region has similarly focused on threatened and endangered fauna and their competitors, predators, or prey. Managers are often asked to design harvest plans based on the California Wildlife Habitat Relationship (CWHR) database, despite ongoing questions regarding the utility of cover-type approaches to modeling wildlife habitat (Schlossberg and King 2009). Further, many assumptions in the CWHR database concerning wildlife in coastal redwood habitats were derived from research in other landscapes. A brief review of available literature on wildlife habitat use in coastal redwood forests suggests that what little is known about wildlife in this habitat is mostly skewed toward observational work on a handful of sensitive species (Table 1).

Table 1. A search of BIOSIS, Google Scholar, and Wildlife Studies Worldwide for taxa-specific wildlife studies in the northern coastal redwood regions of California revealed a strong bias for sensitive species and their competitors, predators and prey.

Taxa	Number of Studies
Mustelids (weasel family)	11
Amphibians	10
Alcids (marbled murrelet)	9
Owls (spotted and barred)	7
Other avian spp.	7
Chiroptera (bats)	7
Ungulates	6
Wood rats	5
Invertebrates	4
Microtine rodents (voles)	4
Corvids (crows and ravens)	2
Ursids (bears)	1
Reptiles	1

From a single-species conservation perspective, then, there is a clear need for additional experimental research on habitat needs of native wildlife. At the same time, such single-species approaches have long been criticized in biodiversity conservation. Most available evidence suggests that the use of umbrella or indicator species rarely produces hoped-for results: prioritizing protection of a suite of species will generally result in conservation of those species, but little else (Lindenmayer *et al.* 2006). While JDSF plays a key role in guiding management decisions for single species conservation, it could play an equally important role in highlighting

the value and success of developing a more holistic view of wildlife conservation under the rubric of sustainable forestry.

Recognizing the growing evidence that single-species conservation may not result in hoped-for conservation benefits, Lindenmayer *et al.* (2006) proposed five broad principles of sustainable forestry to guide biodiversity conservation (see below). While these principles were derived from decades of research into managed forest lands, the majority of long-term experimental management studies in coastal coniferous forests have occurred in the Pacific Northwest (Monserud 2002). Therefore, our understanding of these five principles within the coastal redwood region would benefit immensely from experimental manipulations within JDSF.

Maintenance of connectivity

Within-stand and between-stand retention is believed to play a key role in maintaining wildlife diversity in managed forests. Retention of habitat attributes that promote movement between patches of suitable habitat should therefore be considered a primary goal of sustainable forestry. Most animal movement studies have been observational in nature, or limited to particular spatial and temporal scales. The Savannah River Site Corridor Experiment is relatively unique in presenting an experimental approach to studying both the benefits and costs of habitat connectivity, and has produced a strong body of research since its inception (Levey *et al.* 2005). The project used eight blocks across a managed forest, with each block containing cut patch-corridor designs. Source patches are 100m x 100m (0.4 ac), and corridor "wings" are 25m x 75m. Research here has illuminated theoretical and applied questions about edge effects and dispersal in native and invasive plants, birds, small mammals and butterflies and other invertebrates.

Maintenance of the integrity of aquatic systems by sustaining hydrological and geomorphological processes

Riparian areas are known to serve as critical links between aquatic and terrestrial realms. However, apart from active research on herps on the north coast (e.g. Welsh *et al.* 2006, Fellers and Kleeman 2007, Aguilar *et al.* 2013), surprisingly little research has been conducted within the redwood region on these aquatic-terrestrial links. Long-term interest in food webs at the UC Angelo Reserve has provided insight on terrestrial subsidies from aquatic sources (Polis *et al.* 2004).

Maintenance of stand structural complexity

In relation to wildlife, stand structural complexity is characterized as both the particular attributes available (*e.g.,* multiple age trees, snags, woody debris, and canopy structure), but also their arrangement within the stand. Maintenance of complexity within stands can both promote persistence and connectivity. As with the other principles, structural complexity is assumed to be a net benefit for wildlife, but the particular details for species within coast redwoods is not clear. The value of basal hollows in legacy trees was documented at JDSF by Mazurek and Zielinski (2004). Snags in general are a critical component for many terrestrial vertebrates, but little is known regarding animal use in relation to snag distribution and dispersion, snag numbers, the importance of snags within a landscape scale, and the development of green tree retention into snags. Most studies have focused on animal use (or non-use) of snags, but have not tied snag characteristics to population-level responses (Kroll *et al.* 2012).

Another poorly studied character of structural complexity relates to the importance of mixed conifer-broad-leaf stands. A broad-leaf understory promotes invertebrate abundance (*i.e.,* prey items) and macrofungi abundance (which could lead to snag promotion), and is assumed to support habitat for a diversity of terrestrial vertebrates (Hagar 2007), but little work has been

conducted in the redwood region. While the importance of vertical canopy structure has been well-studied across vertebrate taxa (although less so in coastal redwoods), horizontal heterogeneity, especially in relation to scale, is less understood (Wilson and Puettmann 2007).

Finally, the role of wildlife in maintaining heterogeneity is well-studied in the northeast (*e.g.,* DeGraaf *et al.* 1991) and boreal regions (Edenius *et al.* 2002), but less work has been conducted in the coastal coniferous forests of interest. While browsing is known to play a strong role in reducing cover for some plant species, the role of seed dispersal by browsers is less understood (Gill and Beardall 2001).

Maintenance of landscape heterogeneity

Landscape heterogeneity is assumed to be a net positive for wildlife, although as with most management practices may have trade-offs between species. For example, landscape heterogeneity has been shown to mitigate predation risk for elk (Kauffman *et al.* 2007), while increasing nest predation on edges in songbirds (Vetter *et al.* 2013). As with other questions in coastal conifer forests, our understanding of the influence of landscape heterogeneity on wildlife diversity is generally limited to experimental plots in the Pacific Northwest; these studies are complicated by the checkerboard landscape of much of the managed forests in that region. Further, the scale of stand-level heterogeneity vs. landscape heterogeneity is mediated entirely by the species of interest (Puettmann and Tappeiner 2014).

Use of knowledge of natural disturbance regimes in natural forests

In brief, maintaining or mimicking natural disturbance regimes is assumed to promote native wildlife biodiversity. Apart from the clear association of some species to recently burned landscapes, wildlife response to and interaction with natural and artificial disturbance regimes and plant succession is poorly understood (Cushman *et al.* 2011). Understanding the role of climate in changing terrestrial vertebrate communities may be improved with novel species distribution models (*e.g*., Phillips *et al.* 2006), but especially by models that incorporate community-level inputs (*e.g*., Harris 2014).

Research Needs and Themes

Maintenance of connectivity

Attributes related to within-stand and between-stand retention are of particular interest. Habitat attribute management that promotes movement between patches of suitable habitat could be researched. This would include direct-measured movement in forest clearings and edges; an altered management technique following the broad design could test assumptions about movement in forested landscapes. Incorporating connectivity at larger scales could further strengthen this approach, and situate our understanding of connectivity within coastal redwood forests. The Management Plan includes direction to manage Class I and II Watercourse and Lake Protection Zones (WLPZs) for late seral development, thereby creating an opportunity to conduct research on many different scales of connectivity.

Maintenance of the integrity of aquatic systems by sustaining hydrological and geomorphological processes

Aquatic and terrestrial habitat linkage via riparian areas are important but have not been well studied in the redwood region. JDSF could play a key role furthering the understanding of the management effects on riparian habitat and associated semi-terrestrial and terrestrial vertebrates. These studies could benefit by linking directly to research in Focus Area 2.

Maintenance of stand structural complexity

The arrangement of both habitat type (snags, woody debris, and variety of trees) and their distribution can benefit wildlife. Little is known regarding animal use in relation to snag distribution and dispersion, snag numbers, the importance of snags within a landscape scale, and the development of green tree retention into snags. These knowledge gaps are particularly severe for small mammals (including bats) and cavity-nesting birds.

Vegetation composition as well as structural diversity has a role in wildlife diversity. While the importance of vertical canopy structure has been well-studied across vertebrate taxa (although less so in coastal redwoods), horizontal heterogeneity, especially in relation to scale, is less understood (Wilson and Puettmann 2007). Browsing and seed dispersal by wildlife can influence plant distribution, form, and quantities. Exploring various attributes of stand structural diversity importance to wildlife could help evaluate the relative value of structures that are be developed in the different landscape allocations within the Forest.

Maintenance of landscape heterogeneity

In contrast to stand level heterogeneity, landscape heterogeneity may require a large watershed or regional scale to evaluate. The east - west gradient at JDSF may be able to provide insight in the relative importance of heterogeneity across the landscape. On a bigger scale, JDSF is situated within a much larger landscape and research across sites within Mendocino County, or even at the level of the entire coast redwood range, could provide novel insights into the role of landscape heterogeneity in community assembly.

Use of knowledge of natural disturbance regimes in natural forests

Wildlife diversity may tie to natural disturbance processes. Testing the effectiveness of mimicking natural disturbances is particularly relevant in JDSF's Late Seral Development Areas; other land owners in the redwood region with a similar management goal could benefit from the knowledge gained. Existing disturbance factors on the Forest include the presence of SOD and multiple invasive plants. Increased knowledge regarding changes to wildlife habitat from a variety of disturbances will provide relevant information for the region. Only limited research has been conducted on the role of wildlife in either suppressing or facilitating spread of invasive species.

In addition to the examples included in the five broad principles of sustainable forestry above, specific research needs that could be addressed on JDSF include: habitat relationships for non-listed species and improving or developing an alternative to the CWHR system for managed redwood forests. Single species studies can help provide the information needed by managers to provide better understanding of wildlife habitat in the redwood region.

Impacts of wildlife on habitat

While the responses of wildlife to habitat conditions have been extensively studied, the reciprocal impact of wildlife on habitat has received less attention. A growing body of research has focused on the importance of wildlife as ecosystem engineers (Jones *et al.* 1994) and on the importance of trophic cascades (Estes *et al.* 2011). Through predation, herbivory, and abiotic modifications, wildlife may play key roles on habitat function and structure in coast redwood systems. The introduction of deer to coniferous island forests of British Columbia simplified understory plant and bird communities, while increasing litter arthropods (Martin *et al.* 2010). A study of ensatina (*Ensatina eschscholtzii*) enclosures in a tanoak-Douglas fir forest in northern California resulted in a significant reduction in invertebrate density and an increase in

litter retention (Best and Welsh 2014). JDSF is well positioned to support experiments on key wildlife species to study their impact on key habitat variables through exclosure and enclosure manipulations.

Example Projects

- Ecology is increasingly confronted with a vast array of data collection techniques, while limited by the ability to analyze and interpret the data. Automated acoustic monitoring may provide a cost-effective and robust tool for studying bats and birds in JDSF (Blumstein *et al.* 2011).

- LiDAR systems could provide invaluable measures of stand structural complexity, snag density, and landscape heterogeneity (Martinuzzi *et al.* 2009).

- Non-invasive genetic techniques have proven useful in detecting species occurrence (Zielinski *et al.* 2007), and estimating connectivity by measuring relatedness of populations (Epps *et al.* 2005). Structural equation models have provided novel approaches to understanding animal-plant community dynamics (Prugh and Brashares 2012).

- Research management actions that will conserve native plant communities and improve their ability to resist or adapt to invasive species. The Forest and region are challenged by invasive weeds and pathogens as well. Organisms such as SOD can disrupt existing habitat and increase both fire risk and intensity. These organisms may confound ongoing and future forest research.

- Demonstrate the creation of specific structural habitat elements for wildlife (*e.g.,* brushy areas, large woody debris and snags). Habitat creation would be a procedural demonstration of how to create structures. When structures are created, new questions arise, such as whether created snags are as valuable to woodpeckers as naturally developed snags.

- A macroecology approach could be used to demonstrate the role that landscape-level wildlife diversity plays in contributing to site-level presence or absence of species of interest (*e.g.,* Ramage *et al.* 2013; Veech *et al.* 2007).

- Construct deer exclosures across a range of forest treatments to understand their effects on regeneration.

- Assess the impact to wildlife species from SOD related mortality.

- Create or enhance analytical tools to help assess the wildlife value of managed redwood forests.

- Conduct species specific studies that will aid in the evaluation of effect of timber harvests on wildlife.

Forest Conditions and Scale

The five principles for sustainable forestry guiding biodiversity recognize scale as an important element. Minimum scale could be limited to an individual structural element such as a snag or small gap. Topographic position and stand structure surrounding the element will be a relevant variable. A more robust scale would include a stand or sub-watershed with a specific forest structure. Addressing landscape scale heterogeneity will require the scale to be expanded forest-wide and beyond. Most treatments planned for the Forest will replicate scales relevant to forest managers throughout the North Coast; therefore, in general, no additional consideration of spatial scale specifically for wildlife-habitat relationships may be necessary. However, the planned forest-wide corridor (*i.e.,* Old Forest Structure Zone) and the WLPZs will support research at the landscape level that might not otherwise be possible in other working landscapes on the North Coast. An additional consideration might be at the individual structural level. Given the importance and interest in snags as valuable habitat elements for wildlife, treatments might be developed to generate a wider range of snag types and densities across otherwise similar treatment plots. These manipulations would allow researchers to directly test the impact of various retention strategies' on wildlife abundance, survival, and species richness.

Focus Area 4 – Managed Redwood Forests' Climate Change Adaptations and Role in Carbon Sequestration

Carbon sequestration and climate change studies may be integrated into any of the previously identified Focus Areas or a unique research project may be developed to address these important topics. Though climate change adaptation and carbon sequestration are distinct topics, the implications of carrying out these types of studies on the Forest are similar. This topic is of considerable current interest. JDSF can provide the context in terms of stand conditions and silvicultural responses to contribute towards increased understanding of carbon sequestration and climate change in managed redwood and coastal mixed species forests.

Current Knowledge

Carbon Sequestration

There has been remarkably little work done on productivity in redwood forests in comparison to other forest types in California. Thus there is an opportunity to provide near-term benefits to JDSF by addressing gaps in the research. A study by Busing and Fujimori (2005) and work by Jones and O'Hara (2013) are among the rare attempts to quantify productivity in redwood. While there has been abundance of research conducted on allometry of Douglas-fir and numerous other conifer tree species, redwood and some hardwoods have largely been ignored (Jenkins *et al.* 2003a, 2003b).

Methods to Quantify Above Ground Carbon

Several different approaches may be taken to estimate above-ground biomass for trees. One method is to estimate volume using established or locally adjusted volume equations, and then derive estimates of biomass from volume (*e.g.,* Jones and O'Hara 2013). These methods typically employ assumed or measured wood density and carbon percentage (often assumed to be approximately 50%). The importance of the precision of these proportional values is dependent to a certain degree on application. If one is interested in a comparison of, say, effects on stored carbon of contrasting management options, then the difference is probably minimal unless there is some reason to suspect a treatment effect on wood density. However, if

one is interested in precise accounting of stored forest carbon, these values become more important.

A limitation of the method using volume is that it ignores carbon in the bark, branches and leaves, depending heavily on starting with a reliable volume estimate. Then the proportions for bark, branches and leaves are generally assumed to be constants. Furthermore, treatments may affect the relationship between the estimated bole biomass and these other components, such as leaves (Ritchie *et al.* 2013), so constant proportional adjustments may be inappropriate. Wood density also is sensitive to stand density in some species, although the trends vary considerably (Zhang 1995). One benefit of this approach is that it focuses on the portion of the forest carbon pool that may most effectively be maintained for the long-term; that is, the merchantable portion of the bole and it represents a large component of the total carbon pool (Malmsheimer *et al.* 2011).

A second approach for estimating biomass is by direct estimation of above-ground biomass with allometric equations (Jenkins *et al.* 2003a; 2003b). For some time this approach has been beset by problems with inconsistencies with methods and reliance on inadequate samples. Past research in biomass relationships has often produced unreliable equations because sample sizes were too small, resulting in high degrees of error of prediction. Limited range of sample sizes often resulted in extrapolation of equations well beyond the range of the data, further compounding the error of estimation problem. Efforts are underway to develop equations with a more standardized approach (Temesgen Hailameriam, personal communication, Oregon State University).

A third estimation approach is to use tabular proportional compilations modified by observed or predicted volume (Smith *et al.* 2006). This is a black-box, and it isn't clear how much error is to be expected from this approach, but the benefit is in the ease of application.

Another area of interest, given the high productivity of the forests at JDSF, may be obtaining precise estimates of biomass (carbon) in the understory. While there are some studies related to understory biomass (*e.g.,* Brown 1976; Harrington *et al.* 1984; McGinnis *et al.* 2010), they are very few and limited in their applicability due to model form (Brown 1976) or limited data (McGinnis *et al.* 2010).

Below Ground Carbon

Substantial carbon can be sequestered below ground both in soil carbon and in the root systems of live and dead trees. Below-ground studies tend to be expensive, often involving excavation (Westman and Whittaker 1975; Phillips *et al.* 2011; Omdal *et al.* 2001) of root systems, or more recently the use of ground penetrating radar (Butnor *et al.* 2001; Butnor *et al.* 2005). Soil cores can also be used, but this is more often a method used in studies of fine roots rather than below-ground biomass (Makkonen and Helmisaari 2009). There remains some question as to how valuable they are, given the difficulty in sampling all of the biomass below ground to sufficient depth to cover the extent of large roots. A recent study of redwood and Douglas-fir employed ground penetrating radar to relate root biomass to above ground basal area and leaf area (Caldwell and O'Hara in press). In this study, it was found that significant root biomass may be located beyond the effective depth of the device. An earlier study (Sanderman *et al.* 2008) in the Caspar watershed quantified dissolved organic carbon levels in the soil.

Carbon Sequestration in Response to Management

Tracking carbon sequestration in response to management is a goal which could produce more immediate results. There are a number of tools available to help in this regard. There is increasing emphasis being placed on identifying models and procedures for reliable and consistent biomass (carbon) estimation (*e.g.*, Jenkins *et al.* 2003; Jenkins *et al.* 2004). Also, the National Biomass Estimator Library (NBEL) may be of help in carbon calculations; it is located at: http://www.fs.fed.us/fmsc/measure/biomass/index.shtml.

Climate Change Adaption

Climate change adaptation is a more problematic aspect of this Focus Area. It is not clear what the future holds for climate at JDSF. Climate models do not disaggregate well to the local level so while global or regional trends may be modeled to some degree, the same cannot be said for the local level. For example, the local influence of upwelling on summer fog and temperatures at JDSF may overwhelm other global trends in both temperature and precipitation. Temperatures may decrease with forecast increases in upwelling (Bakun 1990), or increase with recent observed decreases in the degree of upwelling (Johnstone and Dawson 2014). While the global forecasts are for warming temperatures, there is no such consensus for the north coast of California (Cayan *et al.* 2008) because of the diversity of California's landscape. Long-term precipitation forecasts for the north coast have a high degree of uncertainty associated with them (Reid and Lewis 2011). Without a clear understanding of how climate is likely to change on this particular landscape, it is very difficult to develop productive strategies for managing toward climate adaptability of forests at JDSF.

Research Needs and Themes

The most pressing research need for carbon accounting at JDSF will rely to a certain extent upon the methods employed and by deciding on which carbon pools are of greatest interest for application at JDSF. For example, the use of a volume-based approach would suggest that efforts be made to improve volume estimation for species such as tanoak, chinquapin, and madrone which are of little commercial value and thus may have very limited volume models. In general, species of high commercial value (*e.g.,* redwood and Douglas-fir) have received greater focus and thus existing volume equations may suffice.

Carbon Sequestration

With regard to carbon sequestration, there are several potential areas for immediate work that might be productive at JDSF. One important need is to develop more precise quantitative methods for estimating forest carbon. As noted earlier, there is little work that has been done in coastal redwood biomass estimation. Also, equations for hardwood trees and shrubs are generally lacking (Snell and Little 1983). Because of the paucity of root carbon work in the redwood region, any work in this area likely fills a knowledge gap.

Monitoring to Address both Climate Change Adaption and Carbon Sequestration

As noted previously, there is no consensus regarding the future climate trends in the redwood region. Monitoring is the best approach at this point. Monitoring will help detect and quantify changes. In many cases these data sets can help develop or validate carbon models.

Monitoring the Forest over time at JDSF can provide a basis for quantifying any changes that may be taking place with terrestrial vegetation. The existing Continuous Forest Inventory (CFI) protocol may well be a contributing element to meet this need but changes are likely necessary

to: (1) take advantage of emerging technologies, (2) better quantify species responses over time, and (3) address scale issues with traditional inventory designs.

Traditional CFI plots typically provide little information on understory development and are often arranged at too coarse a scale to reflect some trends with regard to species adaptations over time. Additional planning may be needed to address limitations of both the CFI and temporary plot designs. It may be possible to modify one or both of these sampling efforts to changes over time for changing climate, or other factors such as sudden oak death.

LiDAR is one emerging technology that may be used to refine estimates for a landscape when field sampling is limited (Næsset 2002; Zimble *et al.* 2003). Modifications to the existing CFI protocol may greatly enhance the potential for LiDAR-based estimates of forest resources. Raster-based estimates of the land base for critical elements such as canopy cover, snag density, biomass, and volume may be derived given the proper spatially referenced ground data (Wing *et al.* 2012).

For both LiDAR and traditional CFI, some monitoring considerations include: (1) spatial referencing of trees and plots, (2) augmenting dimensional metrics (3) distribution of key species (*e.g.*, invasive or rare plants) on the landscape and, (4) coordinated overstory and understory sampling.

As numerous forest landowners and organizations are interested in carbon work, collaborating and engaging with other researchers who are addressing climate change effects on redwood ecosystems would further the current body of knowledge. JDSF, as a managed public forest, can fill a unique role to provide information on carbon dynamics in redwood ecosystems.

Example Projects

- Establish a protocol whereby forest carbon will be quantified on JDSF, and then identify and prioritize the types of projects that will address weaknesses, inconsistencies, imprecision, or data-gaps related to that particular approach. Consideration needs to be given to the difference in scale between project-level estimation and forest-level estimation.

- Refine methods and models for estimating biomass and carbon in the redwood region. Generally, information on species other than Douglas-fir is needed. Biomass models for hardwood species and understory shrubs found at JDSF are generally lacking.

- Study the flux of carbon in managed and assumed reference (no harvest) forest structures. Examine short and long-term rates and the fate of carbon in a range of management scenarios.

- Investigate the storage and flux in above- and below-ground carbon. Build on soil carbon studies already conducted at JDSF and relate this to existing growth and yield models.

- Data management and coordinated acquisition strategies are needed to achieve informational goals related to changes in terrestrial vegetation over time. There may be opportunities to strategize the optimal methods for monitoring to quantify dynamics with respect to climate change.

Forest Conditions and Scale

This Focus Area is less dependent on scale than the other Focus Areas, although a range of stand structures for comparison along the east to west gradient may be important. The forest-level versus project level estimations will require sampling in not just the upland more managed areas, but riparian and other less managed areas. Monitoring for some yet unknown response to changing climate over time may prove useful for some parameters. However, whether change will be measurable in a riparian area while the upland areas are proven to more resilient or vice-versa is unknown. A uniform grid across the Forest may, therefore, not be the optimal arrangement of sampling structures (*e.g.*, plots, transects, etc.) for this particular area of interest. Areas of restricted acreage or not uniformly distributed across the landscape, such as the pygmy forest or riparian areas respectively, may not be captured to a sufficient degree by a uniform forest-wide sampling grid. In such cases, a more focused sampling design is often more appropriate.

Chapter 4. Desired Future Conditions

The 2008 JDSF Management Plan identifies the range of forest structures that will be developed and maintained at JDSF in order to support both research and sustainable forestry. Proportions shown in Table 2 below will be achieved over time by implementing the allocations or land designations described in the following chapter.

Table 2. Desired Future Forest Structure Conditions from 2008 Management Plan.

Stand Level Forest Structure Condition	Percent of Forest Acres
Late seral stands or old-growth groves	15-25
Older forest structure	10-20
Mature and large trees	5-15
Mixed age and size	30-40
Regeneration and pole-size younger trees	10-20
No specific structure assigned	0-10

The JDSF Management Plan provides both graphics and a description of the forest structure condition classes.

It defines the Late Seral or old growth class as being dominated by large trees and having multiple canopy layers, relatively few trees per acre, and substantial amounts of large, down wood. These stands have some canopy gaps and a limited understory.

The Management Plan describes the Older Forest Structure class relative to Late Seral forest as having more trees per acre, but still retaining multiple canopy layers and substantial numbers

of large trees, snags, and down woody material. These stands consist of a mix of tree sizes. Because there is a wider range of tree sizes, more trees can be growing on a given acre than in the Late Seral structure class. These stands also display some canopy gaps and more mid- and small-sized trees filling those gaps than in the Late Seral class.

The Mature and Large Trees class is described as still having multiple canopy layers, but with a somewhat more open stand structure. There is a clear presence of gaps in the upper canopy that are occupied by clusters of smaller trees. As compared to the previous structure classes, the Mature and Large Trees stands have fewer snags and less large, down wood. These stands have the most variation in canopy height, as the more extensive gaps between larger and mid-size tree trees are occupied by smaller trees. The term “mature” has been the source of some confusion. Maturity as used here is defined in an economic context, at a much younger age (60 to 80 years) than, for example, a wildlife habitat perspective.

The Mixed Age and Size class are described in the Management Plan as having a wide range of tree sizes and ages and a larger number of trees per acre than the previous classes. As in the Mature and Large Trees structure class, this structure class also has gaps in the upper canopy, which provide space for thick clusters of regeneration below. There are moderate amounts of snags and down woody debris present in these stands.

The Management Plan describes the Regeneration and Pole-size Younger Tree class as having greatly increased homogeneity of tree sizes. There are some dominant trees, but mostly lower canopy co-dominants. This structure class has the smallest average tree size and the highest number of trees per acre. These stands have a few larger stems as well as a few mid-sized stems, but the majority of the forest is comprised of younger trees. There are also a few larger stems and some hardwoods that result in this class being richer in structure than single age-size classes.

Chapter 5. Silviculture and Landscape Allocation

This chapter describes key management direction and land allocations associated with this Plan. Table 3 summarizes the landscape allocations organized first by the major category then specific location or management direction. Consistent with the Board’s direction, some of the previous allocations were modified to address the conditions needed for this Research Plan. The creation and maintenance of a range of stand structures and seral stages across the Forest was identified as a critical component for future research for all four Focus Areas. Map 1 shows the resulting JDSF landscape allocation.

Silvicultural systems associated with each of the allocations will be those in the most recent Board-approved management plan for the Forest, with the Matrix allocation available for all silvicultural systems as identified within this Plan.

Table 3. JDSF 2015 landscape allocations.

Major Allocation	*Specific Allocation*	*Acres*	*Subtotal*
RESERVES			707
	Jughandle Administrative Pygmy Reserve	246	
	Old Growth Groves	461	
NON TIMBER MANAGEMENT AREAS			761
	Pygmy Forest	494	
	Cypress Groups	163	
	Power Line Right-of-Way	72	
	Conservation Camps	32	
LATE SERAL DEVELOPMENT AREAS			10,877
	Riparian Zone (WLPZ)	7,339	
	Woodlands Special Treatment Area	1,280	
	Marbled Murrelet	859	
	Late Seral Development	1,400	
OLDER FOREST DEVELOPMENT AREA			5,631
SPECIAL CONCERN AREAS			6,6796
	Neighbor Buffer	409	
	Road and Trail Corridor	3,071	
	Domestic Water Supply	137	
	State Park Special Treatment Area	329	
	Research Areas (existing)	2,291	
	Campground Buffer	23	
	Eucalyptus Infestation Area	203	
	Parlin Fork Management Area	220	
MATRIX	Matrix		24,016
TOTAL			48,674

* *Acres have been revised with improved mapping (e.g., old growth); no physical change to the Forest area. There are a few overlapping acreages and refinement of acreage numbers will continue with improving data accuracy.*

Landscape Allocations and Management Direction

Landscape allocation as used here denotes an assignment of a general management regime to a specific area on the landscape. An example would be Older Forest Development Areas, with an associated management regime of selection harvesting methods aimed at fostering large, mature trees for harvest, while also maintaining large decadent structure within the stand. Landscape allocations and their goals are described below. Acreage associated with each

allocation was presented in Table 3 and in Map Figure 1. Acreage values are best estimate with current data, and may be modified as more accurate data become available.

Reserves

Jughandle Reserve

An administrative area designated to protect a tract of pygmy forest within JDSF and manage recreational access to these lands in a manner compatible with human use in the adjacent Jughandle State Reserve. There will be no harvesting within the reserve.

Old Growth Groves

Includes the existing mapped old-growth grove reserves. These areas will not be harvested.

Non Timber Management Areas

Pygmy Forest

A unique type of dwarf vegetation found on old marine terraces dominated by pygmy cypress and other specially-adapted species. This Special Concern Area includes nearly all of the Jughandle Reserve Special Concern Area, along with other pygmy forest stands in JDSF that occur outside of the Jughandle Reserve boundaries. These areas will not be harvested.

Cypress Groups

Stands dominated by pygmy cypress that occur on sites with generally unproductive soils, but not considered true pygmy forest. These areas will not be harvested.

Power Line Right-of-Way

The power line right-of-way, operated by Pacific Gas & Electric, runs through the Forest generally parallel to State Highway 20. The maintained clearing is not available for timber production.

Late Seral Development Areas

Riparian Zone (WLPZ)

Class I and Class II riparian zones (WLPZs) will be managed for the development and maintenance of late seral forest characteristics.

Mendocino Woodlands Special Treatment Area

A special management area adjacent to the Mendocino Woodlands State Park. Silvicultural activities, with limited exceptions, are focused on promoting late-successional forest conditions, maintaining aesthetic qualities, and limiting impacts on the operation of Mendocino Woodlands. (Note: the Railroad Gulch silvicultural study area is not included in this acreage.)

Late Seral Development (includes Marbled Murrelet)

Includes areas adjacent to five old-growth grove reserves, in addition to the upper Russian Gulch State Park and lower Big River State Park areas, which will be managed to develop late

seral habitat conditions potentially suitable for the marbled murrelet. These areas will be managed to promote development of late seral stand conditions to help buffer the adjacent old-growth groves and to enhance the value of these areas for wildlife species that are associated with late seral forests.

Older Forest Development

The goal of Older Forest Development is to manage for structural characteristics of an older coast redwood forest, which includes large old trees, snags, down logs, multiple canopy layers, and a high level of structural diversity while allowing for timber harvest of trees of all ages and sizes.

Special Concern Areas

Buffers adjacent to non-timberland neighbors

Areas along the boundary of JDSF adjacent to non-industrial timberland owners, where a buffer zone is designated to minimize impacts on neighbors.

Road and Trail Corridor

Buffer areas along trails and roads to maintain aesthetic qualities valued by the public. Only a limited range of silviculture is allowed in these areas.

Domestic Water Supplies

Designated areas for domestic water supply in JDSF that are sensitive to disturbance. Only a limited range of silviculture is allowed in these areas.

State Park Special Treatment Area

Areas adjoining State Parks where the application of silvicultural systems must take the values of the parks into consideration.

Research Areas

Areas set aside for various research studies, including Bob Woods Meadow and all of the Caspar Creek Experimental Watersheds Study Area.

Bob Woods Meadow is an unusual meadow that has resulted from the unique geology, soil, and possibly fire history of this area. If conifer encroachment is found to be resulting from change in fire frequency, more flexibility in management may be needed. As such, the land allocation of this area is Research, and management may be implemented to maintain the meadow.

Campground Buffers

Areas immediately adjacent to campgrounds that are managed for public safety and aesthetic enjoyment. Even-aged silviculture is not allowed within the campground buffers.

Eucalyptus Infestation Area

This is an area in the Caspar Creek planning watershed that includes eucalyptus species mixed with the native species (Douglas-fir, redwood, and other species), along with some Monterey pine. This is an area of special management concern because of the need to control eucalyptus

to allow regeneration of conifers in this stand and to prevent the spread of this exotic species on the Forest. JDSF intends to convert this area to native conifer species.

Parlin Fork Management Area

An area adjacent to the Parlin Fork Conservation Camp that is used as a demonstration area for small woodland management.

Older Forest Structure Zone (OFSZ)

This contiguous corridor across the entire Forest incudes several different allocations described above: old growth groves, areas managed with the objectives of late seral development and older forest development areas. Since the 2008 Management Plan was approved, approximately 3,000 acres of OFSZ was added, effectively buffering allocations (old growth groves and late seral development areas). In order to increase research opportunities, the 100-300 foot buffer along its boundary is no longer necessary. Removal of the buffer allows for limited opportunities to compare and contrast future treatment effects.

Matrix

The Matrix allocation generally has the most silvicultural flexibility. Matrix lands are therefore valuable for creating necessary forest structure conditions to support past, current and future research and demonstration projects.

The Research Plan retains the current Management Plan guidance but includes allocation changes allowing for creation of stand conditions that provide higher quality research opportunities. An essential component for the success of this research plan is that management creates a diverse range of stand structures and arrangements on the landscape. The Matrix allocation will provide alternative multi-aged prescriptions and even-aged prescriptions that allow JDSF to maintain a full suite of stand structures across the Forest. This allows JDSF to be the center for research and demonstration of alternative regeneration methods in the redwood region. These should include the full range of methods from multi-aged stands to even-aged stands. This structural diversity should be implemented; within stands, in contrasting stands and in arrangements that will allow for study of, for example, watershed or wildlife resources.

The vast majority of the Matrix will be continued to be managed with uneven-aged management.[1]

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[1] JDSF 2008 Management Plan limits even-aged management as follows: the total area receiving any form of even-aged silvicultural treatments shall not exceed 2,700 acres per decade. Clearcutting is to be conducted only where necessary for purposes of research, demonstration, addressing forest health, or addressing problematic conditions for regeneration; clearcutting for these four purposes is limited to a cumulative maximum of 100 acres per decade. Up to an additional 400 acres may be clearcut per decade, but only for specific research purposes that cannot be reasonably met through any other method.

Chapter 6. Research Administration and Funding

Administration

Administration elements discussed below encompass technical, physical and monetary support for implementing research and demonstration projects at JDSF.

Individual Research Project Development, Review, and Implementation

JDSF Research and Demonstration staff works with potential researchers beginning with project inquiry to project proposal and implementation and on through completion by archiving the completed study. Staff provides information to assist in determining if JDSF can provide a viable study site. For example, manipulative studies may be able to take advantage of ongoing forest management activities such as Timber Harvesting Plan (THP) preparation or road improvements as a mechanism for treatment implementation. The study duration, experimental design, and the types of management activities that can occur in the study area will all be detailed prior to approval of the project.

The Project Application (Appendix 4) is used to document details not generally included in a typical research proposal. The completed application provides the researcher and JDSF an opportunity to document expectations and commitments.

During the research implementation, JDSF staff can provide feedback on sampling protocol and operational aspects. For specific projects, staff may participate in sampling or other tasks as agreed during the planning process. This provides an opportunity for students to work with experienced foresters as well as JDSF staff to learn new ideas or techniques. Annual updates to JDSF staff on research project status are important to maintaining communication and overall project success.

Typically JDSF will be provided an opportunity to review the draft research report. All researchers must provide JDSF staff with a copy of the final report or publication. If requested by JDSF staff, a data set including plot location and protocol will be provided as well.

Although these steps can require significant commitment of staff time, this will increase the usefulness of the research and increase the probability that the research will be carried out as planned. Forest staff's practical experience and local knowledge supplements the researcher's scientific expertise.

Personnel

Research and demonstration support is carried out primarily by an assigned staff. Additional staff can become involved as needed including; additional Foresters, GIS specialist, Wildlife Biologist, or Biometricians. JDSF staff can work interchangeably between the timber sale, recreation, roads and research programs. This enhances operational relevance as well as innovation in the Forest's management.

Documentation

JDSF staff has developed a permanent plot protocol built on decades of experience with long-term studies that researchers will be required to incorporate when relevant to the study. For instance, the project will need to include standard permanent field reference marking methods associated with designating plot boundary and diameter measurement locations.

JDSF data sets are provided to interested researchers. Conversely, researchers are required to provide copies of datasets, procedures and plot locations as specified during the research approval process. Data storage and archiving of studies on JDSF are critical components of data availability as well as continuity for long-term or complementary studies.

Physical Infrastructure

JDSF maintains a Forest Learning Center, a place where scientists can stay free of charge, near the Chamberlain Creek Conservation Camp (approximately 20 miles east of Fort Bragg). As the research program expands, and funding and staffing increase, the facility will be expanded to provide additional research and educational opportunities. A key need is to expand the internet, phone and laboratory facilities at the Learning Center to help facilitate research.

Remote access weather stations (RAWS) are available to JDSF researchers; one on the western edge of the Forest and the other in the middle (http://raws.wrh.noaa.gov/cgi-bin/roman/meso_base.cgi?stn=MCGC1&time=GMT). They are managed by USFS-PSW and MESO WEST, respectively. An additional eastern CAL FIRE weather station will be installed to record a gradient of the climatic conditions within JDSF.

Electronic Infrastructure

JDSF is a part of a State agency with significant public safety responsibility. Policies and limited resources have reduced opportunities for development of a robust web presence and interface. Basic steps to improved web communication are slowly occurring, but much more can be done. JDSF Forest Notes, Reports, and Newsletters are currently available online. Some of the initial improvements that are being proposed include:

- A research and demonstration web page. At this point, the JDSF webpage is comprised primarily of meeting announcements, recreation information, and planning documents. http://calfire.ca.gov/resource_mgt/resource_mgt_stateforests_jackson.php

- Streamlined link to research publications and products from the JDSF web page. At this point, the link to a limited database is only found on the State Forest Page. http://calfire.ca.gov/resource_mgt/resource_mgt_stateforests_publications_reports_search.php

- Description of datasets and the data itself. Currently, the Caspar Creek watershed data are available online at the USFS-PSW Caspar Creek site. http://www.fs.fed.us/psw/topics/water/caspar/caspubs.shtml. A range of map products would be complementary.

- Outreach information to engage potential researchers. This should include introduction to the physical resources, infrastructure and data as well as application materials and contact information.

Research Proposal Review

This Research Plan recognizes that the review and administrative process should be scaled appropriately to the type of research proposed and its potential to affect the Forest. It is an explicit goal of this Research Plan to minimize the bureaucracy, delay and other barriers to conducting research at JDSF, so that researchers will feel welcomed rather than discouraged. Appendix 3 describes the administrative review by the JDSF Research Committee.

In the case of research proposals seeking CAL FIRE funding, a Request for Proposal will be required. Two peer reviews will be solicited which could include CAL FIRE or other agency staff with technical credentials in the particular subject area of the proposed study, or outside scientists. The JDSF Research Committee or Forest Manager will make the final decision on whether or not to fund a study, informed by the peer reviews.

Externally funded research projects are welcome as long as they meet the research project approval criteria for technical and logistical feasibility as described in Appendix 3. All proposed research will undergo review to ensure that it is consistent with the overall management strategy at JDSF, and the goals of the project are achievable with the resources allocated. Review of these projects will be based on operational and technical feasibility and for consistency with this Research Plan.

Research Grant Funding Program

The State Forests program maintains a research grant funding program which is funded by revenues from the State Forests, primarily from timber sales. Additional funding, where available, will be sought to supplement research grant funds.

The grant funding program has fluctuated significantly from year to year in concert with timber sale revenues, ranging from no funding to a high of $600,000. JDSF plans to implement a permanent research fund account that is replenished by timber sale revenues annually, with a goal of consistently awarding a minimum of $100,000 in research funding each year. This funding is in addition to JDSF staff support of an approved project.

Many projects will necessitate multi-year funding and CAL FIRE grant funding distribution will be implemented with this in mind. These CAL FIRE grants as well as JDSF staff support (including infrastructure) should increase the opportunity for project proponents to pursue matching funds from other funding sources (*e.g.,* McIntire-Stennis).

No specific Focus Area will be favored over another. Over time, CAL FIRE will strive to allocate funding among the four Focus Areas based on recognition of the importance of the proposed project. Research proposals will be evaluated for relevance to the redwood region or JDSF management, scientific merit, single projects that address more than one focal area, experimental design, potential for additional outside source funding, and an ability to perform research. The highest ranking proposals will be funded.

Research projects that fall outside of the four Focus Areas will be permitted to compete on an equal basis for CAL FIRE research funds, using the same funding criteria.

Chapter 7. Partnerships, Outreach and Educational Activities

Partnerships

Partnerships are formal relationships with entities beyond JDSF. They are critical to developing relevant research and augmenting JDFS limited resources. JDSF brings the land base, practical and technical expertise, infrastructure, baseline data, staffing and some financial resources to the partnerships. Partners bring scientific expertise, additional financial resources, a different forest setting and a different perspective.

JDSF has over 50 years of history of academic and agency partnerships. One of the most important of these is the long-term relationship with the US Forest Service-Pacific Southwest Research for the Caspar Creek Watershed Study that was described earlier. The State Forests program and the University of California have a research Memorandum of Understanding. JDSF continues to provide research and demonstration results to diverse groups such as the Society of American Foresters, California Forest Pest Council, California Licensed Foresters Association, Forest Landowners of California and the California Forest Soils Council.

The Board expressly supported the formation of a Redwood Region Research Consortium. JDSF will continue to strengthen existing partnerships and build new ones. Given the finite resources at JDSF, the first steps will be directed at improving our capacity as a partner and as a research site. As the breadth and quantity of research increases, additional steps can be taken to initiate the consortium and engage groups with divergent interests. While the Research Consortium has not been formalized, JDSF will seek input regarding research needs from redwood region foresters.

A preliminary list of the partnerships that JDSF intends to develop and strengthen under this research plan includes:

1) Colleges/Universities
2) Local, State and Federal Agencies
3) Cooperatives
4) Watershed Groups and Non-governmental organizations (NGOs)
5) Redwood region forest timberland managers
6) Board of Forestry and Fire Protection committees and working groups. (*e.g.*, Effectiveness Monitoring Committee)

Outreach

Outreach as discussed in this research plan is considered less formal than education. It includes presentations at conferences, workshops, and to different groups ranging from schoolchildren to forest professionals; newsletters, field tours, and online access to research results. Outreach should lead to increased dialogue and sharing of ideas and results. Specific research and demonstration projects provide useful materials for the outreach process.

Like research planning, Outreach is constrained by resources available. The following list includes the outreach priorities under this research plan:

1) Jackson Advisory Group (JAG)
2) Natural Resource Professionals/Organizations
3) Colleges/Universities
4) Forest Landowners
5) Forest Visitors/User Groups

Written and electronic reports and products are an outreach and education product as well. The existing California Forestry Notes and California Forestry Reports can be utilized as well as new media opportunities. Dissemination of information via the World Wide Web could include, but not be limited to, any of the following formats: video clips, newsletter, blogs, or via social media accounts (*e.g.,* Twitter, Facebook, Instagram, etc.). Refereed journal articles, conference proceedings and posters provide another set of outreach materials that are often aimed at a more technical audience.

To the extent that resources are available, public outreach via a new media format will include publication of a periodic update regarding ongoing research, demonstration, monitoring and education activities at JDSF.

Education

Board policy explicitly recognizes education as a function of Demonstration State Forests by Board policy. Education can extend to information dissemination via posters, presentations, publications, tours and web products.

JDSF offers two opportunities not present at other public redwood forests in the region: timber management and direct involvement in research. A variety of education programs and schools have utilized JDSF to further their educational goals, and promoting their use of JDSF will continue. As a local resource, JDSF will continue to be an important destination for school field trips of all levels. Secondary and college students can particularly benefit from the complex concepts that can be illustrated at the Forest, and there are opportunities to engage with these students in monitoring and science activities. Currently, staffing and resources to enable this interaction are limited. Hosting specific college and university natural resource classes including watershed, soils and silviculture will continue to be a priority. These events have resulted in graduate students continuing their relationship with JDSF by choosing it as a site for their research.

Chapter 8. Demonstration

The Forest Management Plan recognized the importance of Demonstrations and provides some guidance. This Research Plan will create additional opportunities for demonstrations.

Demonstrations include management activities intended to provide examples, explanations, feasibility tests and potential components of larger experiments but not developed to the same rigor as a well-developed research project. They can range in scale from operational examples, such as a new method of installing erosion control structures, to creating landscape level stand structure elements associated with wildlife habitat, watershed processes and silvicultural studies. These landscape level demonstrations may be quantified to some degree as part of

the ongoing Forest-wide monitoring effort. In contrast to research, they may not have a control or quantifiable outcome. Formal management demonstrations should include minimum elements that define when and how an outcome can be observed or measured.

The following demonstration goals are identified:

- Suitable research projects such as the Whiskey Springs thinning study will transition to an ongoing demonstration when the formal research has ended.
- Where feasible, use quantitative experimental approach for furthering the education benefits associated with demonstration projects.
- Continue to incorporate demonstration elements into THPs and day-to-day management activities.
- Identify and pursue demonstration opportunities by staying abreast of the scientific literature and communicating with landowners, stakeholders and the public.
- Document and share demonstration results.
- Where feasible, seek opportunities to include demonstrations via the website (videos, etc.)

Chapter 9. Monitoring

This Research Plan for JDSF provides a framework for identifying desired research projects and management activities needed to support them. Monitoring will complement and build on research and management activities. The Management Plan has used the term monitoring for a wide range of activities, including specific components of CEQA mitigation, rigorous formal study, and documentation of observations. This broad definition of monitoring can overlap activities considered to be research and demonstration. Monitoring generates baseline data that JDSF and others use for study purposes including forest inventory, management history, and stream temperatures. Cooperative monitoring can leverage resources and broaden the relevance of the work.

This research plan provides a framework for developing future monitoring efforts such that the monitoring outcomes offer an opportunity for publishable research results. Hence monitoring can directly complement and be integrated into current and future research projects.

As noted in the Management Plan, the interest in monitoring exceeds resources available. Prioritizing potential monitoring projects (*e.g.*, stream temperature and rainfall) will be facilitated by the implementation of this Research Plan. Field monitoring projects that involve substantial amounts of staff time are best approached as research projects. For these reasons, monitoring projects will be subject to similar review procedures as external research projects, with the objective of having a sufficiently sound design and methodology that the results can lead to a peer-reviewed publication.

Chapter 10. Data

Background data is critical to facilitating research at JDSF. These include baseline data as well as spatial and other data sets. Whether considered a demonstration or monitoring tool, the baseline data described below have broad relevance and are the priority for first year funding associated with this Research Plan (*i.e*., LiDAR and associated forest inventory and an additional weather station).

An important example of ongoing Demonstration and Research activities at JDSF is the permanent inventory (CFI) plots that have been in place since 1959 and are re-measured every five years. In addition, a Forest-wide inventory is conducted every decade. JDSF maintains data from these inventories for a wide variety of management activities (*e.g.,* preharvest stand condition, post-harvest stand objectives, silviculture treatments implemented, acres harvested by yarding method, year of operational activity, road construction and decommissioning, etc.). Stream temperature data is collected annually across the Forest as well as many other forest attributes associated with a variety of projects. Information pertinent to JDSF management activities is expanding with multiple databases that facilitate spatial application as well as continuous record-keeping and inquiry opportunities.

LiDAR topographic and vegetation mapping have great potential to aid in many areas of inquiry and management (see Chapter 3). JDSF's steep terrain and dense vegetation means that an adequate budget is necessary for ground-truthing of the data. JDSF is exploring several avenues to acquire LiDAR imagery, which currently only exists for the Caspar Creek watershed. USDA digital imagery has been a valuable resource. Additional imagery could be valuable as well. Partnerships with neighboring land managers will be useful to reduce acquisition costs and confer on methodologies and associated opportunities.

A goal of this Research Plan is to continue to improve the integrated resource information system for JDSF, covering all resource data. JDSF is continually collecting, collating and improving its geodatabases which include a variety of forest attributes; for example: soils, geology, roads, watercourses, terrestrial biology, and vegetation.

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Appendix 1. Technical Experts

Former State of California Board of Forestry and Fire Protection Members

Heald, Robert, retired Forest Manager, U.C. Berkeley Blodgett Research Forest, Georgetown, CA.

Nakamura, Gary, U.C. Cooperative Extension Specialist-Emeritus, Berkeley, CA.

Piirto, Douglas, Ph.D., Professor of Silviculture, Natural Resource Management Department, Cal Poly San Luis Obispo, San Luis Obispo, CA.

Expert Panel of Scientists

O'Hara, Kevin, Ph.D., Professor of Silviculture, Department of Environmental Science, Policy & Management, University of California at Berkeley, Berkeley, CA.

MacDonald, Lee H. , Ph.D., Professor Emeritus, Department of Ecosystem Science and Sustainability, and Senior Research Scientist, Natural Resource Ecology Laboratory, Colorado State University, Fort Collins, CO.

Bean, Tim W., Ph.D., Associate Professor of Wildlife Ecology, Humboldt State University, Arcata, CA.

Ritchie, Martin W., Ph.D., Research Mathematical Statistician, USDA-Forest Service Pacific Southwest Research Station, Redding Silviculture Laboratory, Redding, CA.

Expert Panel Manager

Standiford, Richard, Ph.D., Cooperative Extension Forest Management Specialist, U.C. Berkeley Center for Forestry, Berkeley, CA.

Appendix 2. Board of Forestry and Fire Protection Findings

CALIFORNIA BOARD OF FORESTRY AND FIRE PROTECTION

FINDINGS ON THE RECOMMENDATIONS OF THE JACKSON DEMONSTRATION STATE FOREST ADVISORY GROUP

AND

DIRECTION TO THE DEPARTMENT OF FORESTRY AND FIRE PROTECTION FOR MANAGEMENT OF JACKSON DEMONSTRATION STATE FOREST

July 13, 2011

Introduction

On February 2, 2011, the Jackson Demonstration State Forest Advisory Group presented the Board with its comprehensive review of the Board's approved 2008 Jackson Demonstration State Forest Management Plan. In its report entitled, *A Vision For The Future: The Report of the Jackson Demonstration State Forest Advisory Group*, the Advisory Group sets forth a dynamic and innovative approach to management of the Forest with a primary objective of establishing Jackson as a "world-class forest research and demonstration center." The Advisory Group's *Vision* was the result of over three years of dedicated collaboration and consensus-building by thirteen individuals from differing backgrounds who volunteered their considerable time and expertise for a common cause on behalf of the citizens of the State of California. First and foremost, the Chair, Vice-Chair, and Members of the Jackson Demonstration State Forest Advisory Group are to be recognized and commended for their service. It is the Board's great desire to see the Advisory Group's *Vision For The Future* come to pass at Jackson.

Upon receipt of the Advisory Group's Report, the Board undertook a thorough evaluation of the Group's many assessments, goals, and recommendations. What follows are the Board's findings upon completion of this thorough review. These findings in turn lead to directives for the Department's continued management of Jackson Demonstration State Forest.

I. Findings on the Recommendations of the Jackson Demonstration State Forest Advisory Group

The Board finds that the Jackson Demonstration State Forest Advisory Group's (hereafter "JAG") Recommendations should be adopted for immediate implementation on Jackson Demonstration State Forest under the following conditions and exceptions:

With regard to the Proposed Landscape Allocations:

- The Board adopts the landscape allocation designations recommended by the JAG to be implemented over the ensuing 40 year period and subject to modification by the Board's research governance structure. The Board also adopts the goals defined for each of these allocations.

- Rather than the silvicultural constraints suggested by the JAG for each of the landscape allocations, the Board will instead rely upon the Board's research governance structure, Department of Forestry and Fire Protection staff, and subject matter experts to develop the silvicultural prescriptions appropriate to each of the allocations.

- In the area designated as the "Matrix" allocation, all silviculture not prescribed for a specific research or demonstration purpose, or reallocated by the Board's research governance structure, shall be as prescribed by the Board's Forest Practice Rules for uneven-aged management, Title 14 California Code of Regulations, Sections 895.1, 913 [933, 953], 913.2 [933.2, 953.2].

With Regard to the Proposed Research and Demonstration Framework:

- The Board, in general, endorses the research-oriented management framework and governance structure concepts presented by the JAG. The Board likewise recognizes the critical necessity for a clear, well articulated research plan and supporting governance structure.

- The Board expressly supports the formation of a *Redwood Region Research Consortium*.

- The Board endorses the concepts of a *Research Planning Team, Redwood Research Group*, and *Centers of Excellence*, but does not adopt them as hard structures for implementation.

- The Board assumes the responsibility for developing a research governance structure for JDSF with the assistance of the Board's Research and Science Committee, subject matter experts, Department of Forestry and Fire Protection staff, and the public. The Board's research governance structure will bear responsibility for determining the range of stand structures necessary to fulfill the goal of creating a "world class" research and demonstration forest at JDSF. Once the Board's research governance structure has made this determination, it will then determine what, if any, modifications to the adopted landscape allocations are required.

- The Board does not adopt the silviculture and timber harvest guidelines proposed in the JAG's *Recommended Guidelines for Silviculture Variations in Support of Research and Demonstration.*

- The Board directs that the Research and Science Committee, subject matter experts, Department of Forestry and Fire Protection staff, and members of the public give serious consideration to the JAG's recommended silvicultural prescriptions for each of the landscape allocations as the Board moves forward with development of a research governance structure and strategic research plan.

With Regard to Recreation:

The Board generally supports the JAG's recommendations for recreation on the Forest, but does not support measures to shield recreationists from the realities and educational opportunities associated with timber harvest. JDSF is not a park, but is a public forest with a unique responsibility to demonstrate timber management under the State's Forest Practice Program.

- The Board does not adopt the JAG's *Recreation Recommendation 2* in support of hiring a single contractor to perform both the recreational user survey and recreation plan. JDSF staff must conform to state contracting guidelines like any other state entity and this should be the only constraint imposed upon staff's ability to contract for outside services.

- The Board does not adopt the JAG's *Recreation Recommendation 4* for creation of guidelines for Timber Harvesting Plan preparation for the protection of recreation resources and preservation of aesthetics along highly traveled roads (Hwy 20, Road 350), but continues to endorse the Board-adopted 2008 Forest Management Plan's specific *Management Measures for Recreation* and mitigations for avoidance of impacts to recreation and visual aesthetics.

With Regard to Herbicides:

- The Board does not adopt the JAG's recommendations for herbicide use.

- The Board reaffirms the 2008 Forest Management Plan's provisions for herbicide use.

II. Findings on the Ongoing Role of the Jackson Demonstration State Forest Advisory Group

The Board finds that the JAG has faithfully and diligently fulfilled the duties identified under item "A" of its Charter for the initial implementation period. The JAG is now directed by the Charter to continue the duties identified under items "B," "C," and "D." These duties are as follows:

> ***B. On an ongoing basis:***
>
> ***1. Review of ongoing implementation of the Management Plan, as requested by the Director.***
>
> ***2. When requested by the Director or Board, provide periodic recommendations on forest management policies and the Management Plan.***
>
> ***3. Review and comment on proposed even-aged harvesting.***
>
> ***4. Provide advice to the Director, CAL FIRE staff, or the Board on other specific issues as determined by the Director, CAL FIRE staff, or the Board.***
>
> ***C. JDSF Advisory Group responsibilities defined in the JDSF Forest Management Plan are hereby incorporated by reference.***
>
> ***D. The JDSF Advisory Group will inform the Demonstration State Forest Advisory Group (DSFAG) on the effectiveness of the implementation of the JDSF Management Plan.***

The Board finds that all other duties imposed upon the JAG, including but not limited to the Board's December 8, 2010 interim period provisions for JAG review of all timber harvesting plans, are hereby complete.

III. Findings on Management Direction to the Department of Forestry and Fire Protection and Jackson Demonstration State Forest Staff

The Board finds that with the adoption of the JAG's recommendations as modified herein, there is no further need for the interim management direction provisions adopted by the Board on December 8, 2010. This interim period direction is hereby rescinded, notwithstanding that any Timber Harvesting Plans already in the process of review or implementation utilizing the interim guidance provisions shall proceed in their current form.

The Department and its staff at Jackson Demonstration State Forest are otherwise directed to implement forthwith the 2008 JDSF Forest Management Plan and incorporate the JAG's recommendations as modified herein into the management of the Forest.

Appendix 3. JDSF Research Governance Structure

1. The Forest Manager is responsible for monitoring water, soil, vegetation, atmospheric, stream, visual, fuel, wildlife, archaeological resources and pest conditions, and directs appropriate management activities. The Forest Manager will review proposed research projects and recommend measures to mitigate potential significant adverse environmental effects. The Manager will ensure all projects are feasible and are consistent with the JDSF research plan.

2. Research and demonstration on the Forest will be overseen by the JDSF Research Committee for operational feasibility and for consistency with the JDSF research plan and current Forest policy. Committee members have pre-designated individual administrative responsibility and authority to develop and administer Forest research and demonstration programs, approve Forest research plans and projects, supervise Forest staff and develop budgets.

3. The JDSF Research Committee shall be comprised of the following:

   - The Region Chief or designee.
   - The Unit Chief (who provides oversight for the budget of the Forest and supervision).
   - The State Forest Program Manager (who is responsible for establishing Forest budgets and for coordinating research on all State Forests).
   - The Forest Manager (who is responsible for day-to-day management and long-term viability of the research program and research projects).

4. As needed, the Committee will request input from subject matter experts and Department professional scientists.

5. Specific Committee responsibilities include:

   - Review and approval/disapproval of proposed research and demonstration projects.
   - Forest-wide research plan development.
   - Update the research plan as necessary.

6. All new research and demonstration project proposals are to be submitted to the JDSF Research Committee for review and approval or disapproval. This review will be for operational and technical feasibility, and for consistency with the JDSF research plan. This review will consider potential conflicts with existing research and demonstration. The JDSF Research Committee may delegate approval of research and demonstration proposals to the Forest Manager.

7. At the discretion of the JDSF Research Committee, research projects may be required to contribute to costs of maintenance of the Forest and its facilities that are associated with the projects.

8. The JDSF Research Committee will report to the Board as requested. The research plan is subject to the same periodic review by the Board as the Forest Management Plan. The Board will provide direction on potential future research to the JDSF Research Committee.

Appendix 4. Research Project Application

JACKSON DEMONSTRATION STATE FOREST

Demonstration State Forest Program
California Department of Forestry and Fire Protection

Project Application

APPLICANT INFORMATION Project Contact: Name / Title		
Organization		
Address		City/Zip Code
Telephone Number	Fax Number	Email Address
SPONSOR /ADMINISTRATION INFORMATION Sponsor Contact (Funding Entity, Supervisor or Major Professor): Name / Title		
Organization		
Address		City/Zip Code
Telephone Number	Fax Number	Email Address
PROJECT LOCATION AND TYPE		
Forest(s): [ ]Boggs Mountain [**X**]Jackson [ ]LaTour [ ]Mountain Home [ ]Soquel [ ] Other		
Type of Project: [ ] Research [ ] Demonstration [ ] Monitoring [ ] Other		
PROJECT TITLE		
Deliverables (Type of Report and/or Data):		
EXPECTATIONS: CAL FIRE will receive paper or electronic copies of any final report, publication, thesis or dissertation. CAL FIRE will receive an electronic copy of all data collected, including documentation and location data if requested. **CAL FIRE will be acknowledged in all publications resulting from this project.** **A single page annual update summarizing research progress shall be provided to CAL FIRE.**		

Description of Project (may attach research proposal or equivalent):

Describe how data will be collected on the State Forest, specifically any permanent plots or sampling techniques, for example increment cores or soil. Please be specific about what flagging or plot designations will remain after the project is complete. If study will require area to be undisturbed, please describe the needs and duration.

Estimated Start Date: **Estimated Completion Date:** **Estimated Report Date:**

Request(s) for State Forest Assistance:

Indicate Interest in Lodging:

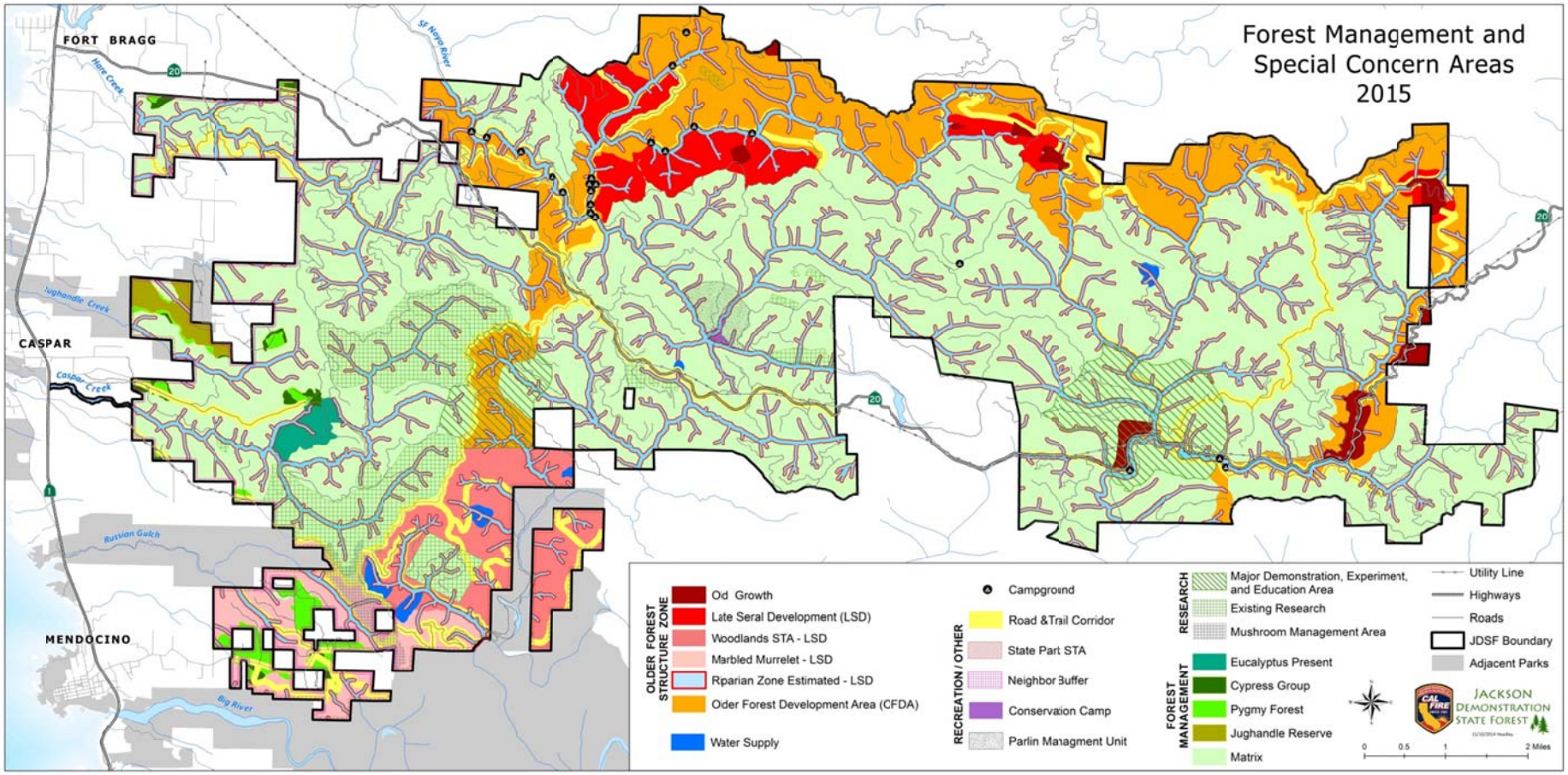
I certify that the information contained in the application is accurate and that any permits required by state or federal law will be obtained before commencing work. Approval of Application will be complete before commencement of field work.

Signature of Responsible Party **Date**

DSF RECORDS
Demonstration State Forest Special Conditions;

Demonstration State Forest Acceptance; **Date**

Appendix 5. List of Acronyms and Abbreviations

Board	Board of Forestry and Fire Protection
CAL FIRE CDF	California Department of Forestry and Fire Protection
CEQA	California Environmental Quality Act
CFI	Continuous Forest Inventory
CWHR	California Wildlife Habitat Relationship classification system
DFW	California Department of Fish and Wildlife
JAG	Jackson Advisory Group
JDSF	Jackson Demonstration State Forest
LiDAR	Light Detection And Ranging
LSD	Late Seral Development Area
Management Plan	Jackson Demonstration State Forest Management Plan (2008)
OFDA	Older Forest Development Area
OFSZ	Older Forest Structure Zone An umbrella term used to describe Older Forest Development Ares, Late Seral Development Areas and Old Growth Grove Reserves.
PSW	United States Department of Agriculture-Forest Service Pacific Southwest Research Station
RAWS	Remote Access Weather Station
SOD	Sudden Oak Death (*Phytophthora ramorum*)
THP	Timber Harvest Plan
USDA	United State Department of Agriculture
USFS	United States Forest Service
WLPZ	Watercourse and Lake Protection Zone

Map 1. 2015 JDSF Land Allocations