Executive Summary

The California Department of Transportation (Caltrans) and California Department of Fish and Game (CDFG) commissioned the California Essential Habitat Connectivity Project because a functional network of connected wildlands is essential to the continued support of California's diverse natural communities in the face of human development and climate change. This Report is also intended to make transportation and land-use planning more efficient and less costly, while helping reduce dangerous wildlife-vehicle collisions.

This Report was produced by a highly collaborative, transparent, and repeatable process that can be emulated by other states. The work was guided by input and review of a Multidisciplinary Team of agency representatives, a Technical Advisory Group, and a Steering Committee. The Multidisciplinary Team (~200 people from 62 agencies) provided broad representation across Federal, State, Tribal, regional, and local agencies that are involved in biodiversity conservation, land-use planning, or land management—and that could therefore both contribute to and benefit from efforts to improve habitat connectivity at various scales. The Technical Advisory Group (44 people from 23 agencies) was a subset of the Multidisciplinary Team. It provided technical expertise to help guide such decisions as selection of data sources, models, and mapping criteria. The Steering Committee (ten people from four partner agencies) guided key decisions about work flow, meeting agendas, and document contents. In addition to review by these agency representatives, the work plan and this final report were subject to peer review by five outside experts in conservation biology and conservation planning.

This Essential Habitat Connectivity Report includes three primary products: (1) a statewide Essential Habitat Connectivity Map, (2) data characterizing areas delineated on the map, and (3) guidance for mitigating the fragmenting effects of roads and for developing and implementing local and regional connectivity plans. These products will be made available for public use on two websites—BIOS, managed by the California Department of Fish and Game (http://bios.dfg.ca.gov), and Data Basin, managed by the Conservation Biology Institute (http://databasin.org). Both are interactive web-based systems that allow users to download, print, combine, comment on, or otherwise use the maps, data layers, and other information.

Essential Connectivity Map (Figure ES-1)

The Essential Connectivity Map depicts large, relatively natural habitat blocks that support native biodiversity (Natural Landscape Blocks) and areas essential for ecological connectivity between them (Essential Connectivity Areas). This coarse-scale map was based primarily on the concept of ecological integrity[1], rather than the needs of particular species.

[1] Natural Landscape Blocks were delineated based primarily on an Ecological Condition Index devised by Davis et al. (2003, 2006) using degree of land conversion, residential housing impacts, road impacts, and status of forest structure (for forested areas) as inputs. This index was modified by also considering degree of conservation protection and areas known to support high biological values, such as mapped Critical Habitat and hotspots of species endemism. Essential Connectivity Areas were delineated using least-cost corridor models

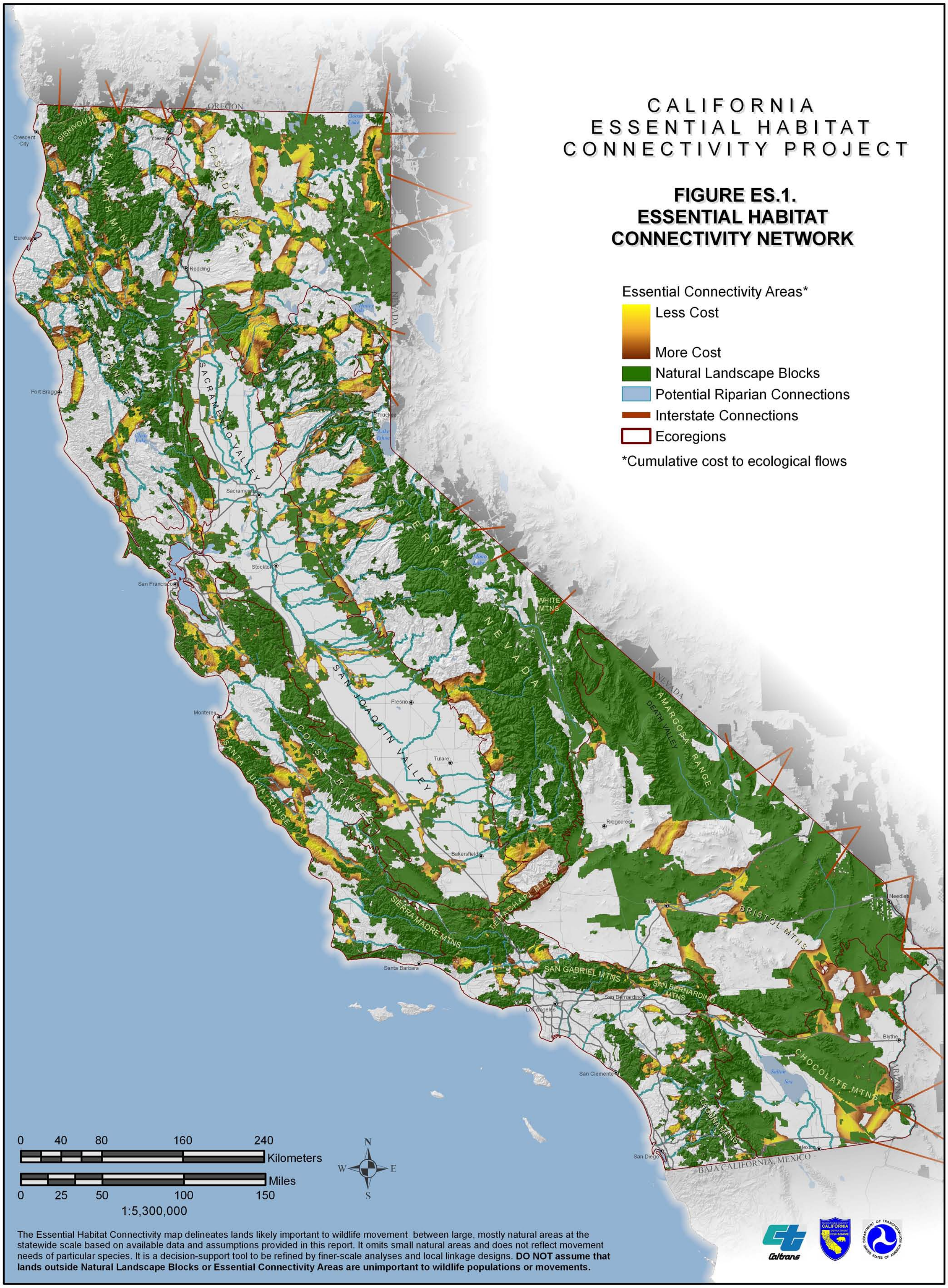

FIGURE ES.1. ESSENTIAL HABITAT CONNECTIVITY NETWORK

Essential Connectivity Areas are placeholder polygons that can inform land-planning efforts, but that should eventually be replaced by more detailed Linkage Designs, developed at finer resolution based on the needs of particular species and ecological processes. It is important to recognize that even areas outside of Natural Landscape Blocks and Essential Connectivity Areas support important ecological values that should not be "written off" as lacking conservation value. Furthermore, because the Essential Habitat Connectivity Map was created at the statewide scale, based on available statewide data layers, and ignored Natural Landscape Blocks smaller than 2,000 acres[2], it has errors of omission that should be addressed at regional and local scales, as discussed in Chapters 4-6.

The statewide essential connectivity network consists of 850 relatively intact and well-conserved Natural Landscape Blocks (ranging from 2,000 to about 3.7 million acres each) with over 1,000 potential connections among them. The 192 Essential Connectivity Areas represent principle connections between the Natural Landscape Blocks within which land conservation and management actions should be prioritized to maintain and enhance ecological connectivity. Each Essential Connectivity Area connects from 2 to 15 (on average 4.3) Natural Landscape Blocks across distances averaging roughly 10 to 20 km. In addition to these Essential Connectivity Areas, there are 522 instances where Natural Landscape Blocks were separated only by a road—in which case there was no need to delineate a connecting polygon, because sustaining and enhancing functional connectivity across roads is the primary or only conservation action needed (Chapter 6). In addition, the map illustrates that numerous riparian corridors contribute to ecological connectivity throughout the state; and sustaining and enhancing riparian and riverine corridors should remain a high conservation priority whether they are inside or outside of Essential Connectivity Areas and Natural Landscape Blocks.

Characterizing Natural Landscape Blocks and Essential Connectivity Areas

Data characterizing the Natural Landscape Blocks and Essential Connectivity Areas—including their size, physical characteristics, biological characteristics, ownerships, and the roads that cross them—are summarized in Chapter 3 and provided in detail in Appendices B and C. These data are also available in electronic databases so that users can select, sort, or weight the various attributes to help prioritize and plan conservation, mitigation, or other actions in or near the Essential Connectivity Areas and Natural Landscape Blocks.

Across the state, Natural Landscape Blocks average about 40% in private ownership and 44% in conservation reserves, with over 90% of their area in natural landcovers. Essential Connectivity Areas average about 15 km long, are about 61% in private ownership, have about 13% of their area in conservation reserves, and are over 80% natural landcovers. However, there is tremendous variability in attributes among California's eight diverse

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run on a data layer that represents the relative permeability of the landscape to wildlife movements, based on land cover naturalness, modified slightly to reflect conservation status.

[2] Only areas > 2,000 acres in size that met ecoregion-specific rules for Ecological Condition Index, degree of conservation protection, and support of known high-biological resource values were considered Natural Landscape Blocks. Only Natural Landscape Blocks > 10,000 acres were connected by Essential Connectivity Areas in most regions, and those > 2,000 acres were connected in more developed ecoregions (San Francisco Bay Area, Great Central Valley, South Coast, and Northern Sierra Nevada).

ecoregions and individual connectivity areas. Within each ecoregion, Essential Connectivity Areas tend to connect the most ecologically intact and well-conserved lands across generally less intact and protected land. However, optimal approaches to sustaining and enhancing functional connectivity will vary between ecoregions and individual Essential Connectivity Areas to reflect different contexts. For example, in the relatively undeveloped forest and desert ecoregions—such as the Sierra Nevada and Mojave Desert—many Essential Connectivity Areas connect highly intact wilderness and park lands across private or federally managed multiple-use lands, which support mostly natural landcovers and are relatively permeable to wildlife movements. In these "low-contrast" situations, managing to sustain wildlife movements between existing protected areas may be the primary conservation approach. In other, more human-altered ecoregions—such as the San Francisco Bay Area, Great Central Valley, and South Coast Ecoregion—Essential Connectivity Areas tend to connect existing reserves across lands with more roads, agriculture, and urbanization, which can constrain wildlife movements. In such "high-contrast" situations, there may be greater focus on restoration and enhancement actions to improve ecological connectivity.

The California Essential Habitat Connectivity network overlaps considerably with other conservation maps, and it should be seen as complementary to rather than replacing existing conservation maps and plans. For example, the network includes 76% of the protected lands in California, including 99.6% of National Parks, 91% of conservation lands administered by non-governmental organizations, 80% of California Department of Parks and Recreation lands, and 80% of various County conservation lands. The network also overlaps with 41% of the area covered by Habitat Conservation Plans and Natural Community Conservation Plans, and 80% of habitat considered essential to recovery of federally Threatened or Endangered species. Essential Connectivity Areas also support high biodiversity, with an average of 26 special status plant and animal taxa per Essential Connectivity Area. On average, 12% of the land area in Essential Connectivity Areas is Critical Habitat for species listed under the Endangered Species Act.

Although the Essential Connectivity Areas were mapped based on coarse ecological condition indicators, rather than the needs of particular species, Essential Connectivity Areas are expected to serve the majority of species in each region. For example, Essential Connectivity Areas in California's South Coast Ecoregion included on average 81% of the area in each of 11 detailed Linkage Designs prepared by the South Coast Missing Linkages project based on the needs of 14 to 34 focal species each. Nevertheless, how well the Essential Connectivity Network actually accommodates wildlife movements is uncertain and will vary tremendously among species and locations. Consequently, future work should focus on assessing functionality of the network for diverse wildlife species and refining the Essential Habitat Connectivity Map and the following recommendations based on the results.

Framework for Regional Analysis

Given the coarse nature of the Essential Habitat Connectivity Map and the difficulties inherent to prioritizing conservation across such a diverse landscape, this Report provides guidance for mapping connectivity networks at regional and local scales. Regional analyses (Chapter 4) are useful to (1) help planners comprehensively consider regional needs for connectivity, including for natural areas smaller than those mapped in this statewide project; (2) prioritize Essential Connectivity Areas for more detailed planning; and (3) take advantage of spatial datasets not used in this Report because they did not cover the entire state. A regional analysis produces a map of all Natural Landscape Blocks (including small blocks), detailed and implementable conservation plans for the most important connectivity areas, and placeholder polygons for the remaining connectivity areas.

A good existing example of a regional analysis is South Coast Missing Linkages and the accompanying 11 individual Linkage Designs for the South Coast Ecoregion (available at www.scwildlands.org). The Linkage Designs were developed based on the habitat and movement needs of multiple focal species, and 10 of the 11 designs are being actively implemented.

In developing a regional connectivity analysis, it is important to involve end-users early in the design process to collectively agree on what types of areas they want to connect, which areas need connectivity, and which areas merit the highest priority for detailed Linkage Design. The entire process should be transparent and repeatable to build trust and allow updating as new or better data become available.

We recommend that regional connectivity analyses identify Natural Landscape Blocks by considering ecological integrity, protection status, biodiversity, and highways, and map Essential Connectivity Areas by least-cost modeling for a broad suite of focal species. In Chapter 4 we describe the advantages and disadvantages of alternative approaches, so that planners can choose the most appropriate methods for their region. If time and budget allow, we recommend conducting detailed Linkage Designs for all potential linkages in a region. More commonly, limited resources will compel planners to develop a few priority Linkage Designs at a time. Nonetheless every regional plan should replace the most crucial placeholder polygons with detailed Linkage Designs using methods described in Chapter 5.

Framework for Local-scale Analyses

The goal of local-scale analyses is to replace the relatively coarse Essential Connectivity Areas with detailed Linkage Designs—that is, maps delineating the specific lands needed to maintain or restore functional connections between two Natural Landscape Blocks and detailed descriptions of the necessary conservation and management actions. Chapter 5 provides a “cookbook” of step-wise procedures for each major step listed below. Except for the new procedures related to climate change, each set of instructions has a well-established history of use for local-scale analysis in California and elsewhere. Each step should involve collaboration among stakeholders, end-users, implementers, and scientific experts.

1. *Delineate Natural Landscape Blocks:* Connectivity is meaningful only with reference to the areas to be connected—whether they are existing protected areas, suitable habitat for select focal species, or other alternatives.
2. *Select focal species:* Choose focal species to represent a diversity of habitat requirements and movement needs. Focal species should include *area-sensitive species* (those with large area requirements, which are often the first to disappear when connectivity is lost),

barrier-sensitive species (those least likely to traverse roads, urban areas, canals, agricultural fields, or other features), and *less mobile species* (habitat specialists and those with limited movements).

3. *Map corridors for focal species:* Conduct least-cost corridor analyses for each focal species to identify one or more swaths of habitat that support movement and gene flow. Consult experts on each focal species to parameterize the model and review the results.
4. *Map corridors for climate change:* Add additional swaths of habitat to increase the utility of the linkage under an uncertain future climate. We offer an approach that identifies corridors based on *land facets*—or areas of relatively uniform physical conditions that represent the arenas of biological activity, rather than the temporary occupants of those arenas.
5. *Evaluate and refine the preliminary Linkage Design.* Even the most permeable landscape identified in the previous two steps may not be very permeable for some species. Therefore, assess the spatial distribution of habitat patches for each species and add habitat as needed to the Linkage Design to ensure each species is accommodated. Where possible, impose a minimum width of 2 km to allow occupancy by medium-sized animals and support networks of linked populations for less-mobile species that require multiple generations to move their genes between Natural Landscape Blocks.
6. *Assess the Linkage Design in the field:* Conduct fieldwork to ground-truth existing habitat conditions, document barriers and passageways, identify restoration opportunities, and consider management options.
7. *Develop a Linkage Design Action Plan:* Compile results of analyses and fieldwork into a comprehensive report detailing what is required to conserve and improve linkage function, including priority lands for conservation and specific management.

Each Linkage Design should be based on existing baseline conditions or (for highly altered areas such as the Central Valley) on context and restorability of habitats, rather than on potential future build-out scenarios. Basing the analysis on future development scenarios may obscure what could be optimal alternatives. Although compromises will occur during implementation, the biological optimum provides a useful reference condition, so that decision-makers can evaluate trade-offs and make good compromises.

Guidelines for Addressing Road Impacts

The ecological footprint of a road network extends far beyond its physical footprint due to road mortality, habitat fragmentation, and numerous indirect impacts. The Essential Habitat Connectivity analysis identified 552 pairs of Natural Landscape Blocks separated only by a road, and numerous roads cross Essential Connectivity Areas. Chapter 6 therefore provides guidelines for assessing where mitigating road impacts to wildlife movement and ecological connectivity will be most effective, along with guidelines for how best to enhance functional connectivity while reducing the hazards of vehicle-wildlife collisions. In locations where a road crosses a Natural Landscape Block in protected status, the strongest enhancement and mitigation measures should be used. Protected status represents a significant public investment and commitment to ecological integrity, and roads should not compromise that investment.

Wildlife crossing structures—such as wildlife overpasses, underpasses, bridges, and culverts—can facilitate wildlife movement across roads, especially when integrated with appropriate roadside fencing. Because species vary tremendously in their reactions to roads, fences, and different types of crossing structures, multiple types of crossing structures should be constructed and maintained to provide connectivity for all species. The structures should be spaced close enough to allow free movement by species with different spatial requirements, and fencing should keep animals off the road and direct them towards crossing structures.

Strategies for Integrating and Institutionalizing the California Essential Habitat Connectivity Project

Maintaining and enhancing functional ecological connectivity across California's landscape in the face of human development and climate change is no easy task, and no single agency or small group of agencies can tackle it alone: The 200 members of the Multidisciplinary Team for this Project volunteered to serve as ambassadors for connectivity within and outside their agencies. As described in Chapter 7, each agency has a unique role to play in conserving ecological connectivity while also pursuing its own mission—whether it involves improving transportation, delivering water and power, providing recreational opportunities, or conserving biological diversity. Connectivity conservation fits all missions to some degree.

The Essential Habitat Connectivity Project was designed to be adopted and used to support planning at multiple scales. At the broadest scale, the products of this Project can serve new or emerging collaborations larger than the state of California, such as the 14-state Western Governors' Wildlife Council. At the statewide scale, the Project was intended to support conservation plans like California's Wildlife Action Plan and the California Climate Adaptation Strategy, and to integrate with infrastructure plans such as California Transportation Plan 2035. At regional and local scales, the products can be used to inform a wide array of planning efforts, such as Natural Community Conservation Plans and Habitat Conservation Plans, transportation Blueprint Plans, city and county General Plans, and land acquisition, management or restoration plans by conservancies, land trusts, and other non-governmental organizations. Private landowners may want to use this information to understand how they can be a part of a regional conservation goal or engage in the discussion. Legislation both supports and assures the conservation of connectivity in California.