ADAR-BASED MAPPING
OF THE
NATURE RESERVE OF ORANGE COUNTY

THE NATURE CONSERVANCY

Prepared by
Ed Almanza & Associates

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ACKNOWLEDGMENTS

The vegetation mapping produced as a result of the work described in this report was funded by the California Department of Fish and Game through a Natural Communities Conservation Program Grant. The Nature Conservancy and the authors gratefully acknowledge this support and the continued interest of the Department of Fish and Game to enhance habitat management activities in Southern California.

ADAR-based Mapping of the Nature Reserve of Orange County
The Nature Conservancy
California Department of Fish & Game

Introduction

coastal subregion of the

An up-to-date baseline map of plant communities is among the most fundamental tools for management of nature reserves. This report describes methods to develop a revised map of existing plant communities within the Nature Reserve of Orange County (NROC), a reserve managed by The Nature Conservancy. The map prepared through this project encompasses most of the area within the coastal subregion of the reserve. The site is within the San Joaquin Hills of coastal southern Orange County. With large areas on both sides of Laguna Canyon Road (State Highway 133), the reserve extends inland from the coast to north of the San Joaquin Hills Transportation Corridor (State Highway 73). Land uses adjacent to the reserve include roads and highways, residences (at various densities), commercial and industrial uses. The reserve itself includes electrical towers and transmission lines, water reservoirs, urban parks and preserved open space.

The objective of this study was to produce a GIS vegetation map for use by The Nature Conservancy and others in monitoring and managing the reserve. Data were derived principally from remote sensing imagery, using the ADAR imaging system[1], with some support from ancillary field data. Additional objectives were to define appropriate standardized methods for mapping the site to meet reserve management needs, and to develop a data base structure that facilitates use in monitoring and management applications. In creating the map, the team attempted to anticipate the specific management tasks likely to be performed in the preserve. The resulting data thus reflects those habitat characteristics and features that will be monitored to support management activities.

General Approach

Earlier studies (Stow et al., 1998; Brewster et al., 1998; Brewster et al. 1999) confirmed the utility of remote sensing (and ADAR imagery in particular) as a source of data on vegetation type and estimates of plant cover, sufficient to serve the management needs of natural habitat preserves. Beginning with ADAR-based vegetation mapping at Mission Trails Regional Park in San Diego (Stow et al., 2002), more recent studies surpassed earlier inquiries of general feasibility and focused on issues of a more site-specific nature, such as ADAR's utility in monitoring changes in vegetation type or vegetation quality over time. Development of this new map for NROC marks a transition from the preliminary stages of research and development to the fully implemented application of ADAR-based acquisition and classification for baseline

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[1]The "ADAR" (Airborne Data Acquisition and Registration) imaging system provides land cover data in a multi-spectral, digital format. For background information on the system and its previous application for habitat mapping see Stow et al., 1998. For data acquisition parameters and metadata related to the ADAR imagery obtained for this project, see Appendix A of this report.

vegetation of a managed reserve. The map product developed through this project will not only provide baseline data, but will also serve as the basis for future monitoring of changes in habitat type and quality, as well as for effectiveness monitoring of future management programs in the Reserve.

A basic premise of the project is that development of a data base should not be undertaken without careful consideration of the uses to which the data will be applied. The mapping effort must anticipate future management activities and the specific issues relevant to monitoring habitat at the site. Our first step, therefore, was to identify the map's principal uses. This was followed by three subsequent steps: defining characteristics of map data; defining suitable methods for extracting appropriate data from the ADAR imagery; and finally, identiying an appropriate data structure to serve management applications. The methods and results of these tasks are described below.

The New Map's Anticipated Uses

Previous studies identified the information needs for monitoring and management preserves of the Natural Communities Conservation Plan (NCCP) (Almanza, 1998; NCCP Core Group, 1997). The Management Plan for the Orange County NCCP further prescribes site-specific monitoring objectives for the reserve. The approach taken in this project builds on these and other related studies to develop feasible methods for monitoring habitat quality in coastal scrub communities. Recent work (Stow et al., 2002) addressed the specific question of monitoring habitat quality by convening a team of preserve managers, wildlife ecologists and habitat conservation specialists to develop a consensus on the critical variables that comprise habitat quality. The team determined that, for purposes of landscape level monitoring, two key variables act as strong indicators of relative habitat quality in the coastal sage scrub plant community. These are: (1) shrub cover (measured as percent cover), and (2) the abundance of exotic (weedy) plant species (also measured as percent cover). These two parameters meet key requirements for practical landscape-level monitoring: they provide quantifiable observations that are (a) empirically related to habitat quality and (b) detectable through remote sensing technologies.

Based on these sources and lengthy discussion with The Nature Conservancy~~'s reserve management s~~taff, we identified several tasks as anticipated applications for the updated map.

Monitor changes in:

- (a) Habitat type (by plant community category)
- (b) Size and/or configuration of mapped habitat
- (c) Species composition and/or changes in percent shrub cover within habitat types
- (d) Densities, distribution and species of exotic plant species
- (e) Recreational effects, such as new or widened trails
- (f) Fire recovery

In addition, the baseline map must also facilitate other activities:

(g) Inventory mapping of individual stands and populations of high interest species of plants and animals
(h) Research in the abundance, presence/absence, distribution and habitat relationships of high interest species
(i) Research in habitat characteristics, their spatial relationships and spatial relationships with other environmental variables

Habitat changes of the types identified above have been successfully detected previously using ADAR-based maps during pilot studies within the NROC site (Brewster, 1998). The use of vegetation base-maps in a GIS format to facilitate research and inventory tasks has also proven feasible through other GIS mapping efforts, including use of the County of Orange GIS data base for similar tasks within the reserve.

Defining Map Data Characteristics

The task of defining the type and characteristics of data is inextricably linked to the specific methods used for extracting data. We began by identifying some broad parameters for the type of data appropriate to the map's anticipated uses. Foremost among these considerations is the need to decide on an appropriate classification system for mapping vegetation types. The County of Orange completed vegetation mapping of the study area at a scale of 1"=500' in 1993, based on a classification system initially developed by Dames and Moore (Gray and Bramlet 1992), and later revised by Jones and Stokes (1993). This classification of plant communities was initially based on a report prepared by the California Department of Fish and Game (Holland 1986). However, due to the concern about the utilization of scrub communities by several listed or special interest wildlife species, a more extensive classification system was developed for shrub communities based on various studies or proposed scrub classifications for southern California. Among the most important of these studies are Kirpatrick and Hutchinson (1997), and DeSimone (1989) on coastal sage scrub communities, along with a proposed classification of southern California plant communities (Paysen et al. 1980), and scrub communities (Gordon and White 1994) by the U.S. Forest Service. The majority of the proposed sage scrub and chaparral classification system has subsequently been incorporated, as shrub dominated series, in *A Manual of California Vegetation* (Sawyer and Keeler-Wolf (1995), that has been adopted for use by the California Department of Fish and Game (CNDDB 2002) in the agency's mapping of plant communities.

The map of the area previously prepared by Jones and Stokes for the County of Orange has been variously criticized for being "too general," "too detailed," "too botanical in orientation," "too gross in scale," and "spatially imprecise". Many of these criticisms stem from constraints imposed by the specific objectives and methods associated with the map's production in 1993, including limited field checking and difficulties in co-registering data with topographic maps. Additionally, the map has often been employed for many applications other than those for which it was originally intended. Moreover, the extensive wildfire in Laguna Canyon of 1994 rendered much of the map obsolete.

In our work, some discussion was given to developing a new vegetation classification scheme more tailored to reflect the particular habitat requirements of high interest wildlife species in the reserve. Consideration was also given to modifying the standard Jones and Stokes scheme to better reflect post-fire plant communities that have developed since the previous mapping. We also considered using a mapping scheme keyed on the relative abundance of *Rhus* as a major determinant in classifying individual polygons. In the end, through an iterative process in the field, the team determined to employ the previously used Jones and Stokes scheme with some modifications (see subsequent discussion below). The modified Jones and Stokes scheme was believed to best reflect the patterns and variability of habitats in the Reserve.

A second major consideration in defining appropriate characteristics of data is the size of minimum mapped units. The minimum mapped unit is the smallest polygon size (or minimum resolution) at which the map identifies individual, distinct, classified vegetation units. It is usually based on either the limits of the spatial resolution of the primary data source (e.g., aerial photographic resolution, or pixel size in the case of digital imagery) and/or budgetary constraints often manifest as limitations in the man-hours spent by biologists mapping in the field. While this project also had its budgetary limits, the spatial resolution provided by our primary source of data (0.5 m) was not a limiting factor for plant community level mapping. The minimum size of our polygons would be limited, we recognized, by the practical limits in delineating the intricate patterns of inclusions and very small patches that often occur in the habitat types that occupy our site. The difficulty in separating various scrub communities is related to the fact that they represent a continuum of species along various environmental gradients. Since these communities are determined by the dominance of various co-occurring shrub species, they can be difficult to separate in the field. In addition these communities often contain inclusions of smaller communities and/or elements of other communities, such as chaparral species that increase the complexity of mapping the series of coastal sage scrub or chaparral found at any particular locality.

A paramount consideration in defining minimum mapped unit size is the set of applications anticipated for the map product. The suite of management tasks and objectives cited above are activities that occur and will be monitored at the landscape level scale – as opposed to the larger scale at which subregional preserve boundaries are designated (the application for which the 1993 Jones and Stokes map was generated), or smaller scale applications, for example, micro-managing individual populations of rare plant species.

Based on this consideration, and the practical limits of defining distinct units among the highly inter-mixed vegetation types of the NROC site, we resolved to define the scale of our mapped units according to two rules: (1) we would develop the map according to "management units", *i.e.*, in subsections of relatively discrete, identifiable geographic areas (usually defined by topographic features, such as watershed divides) that are not only likely to be managed as individual units by the NROC managers, but also exhibit more or less unifying characteristics; (2) mapping would be at the landscape scale; it would exhibit the relatively large scale of the landscape of the individual management unit, but reflect and respond to the scale and variability in the landscape. The size and configuration of mapped units would be influenced by landscape differences in slope and aspect. Where appropriate, polygons would conform to such features as a canyon bottom, knoll or ridgetop. Smaller units would be integrated when they are readily distinguishable in the imagery (and/or in the field) and are sufficiently distinct to lend themselves to mapping at a scale consistent with the overall complexity of the management unit as a whole. These rules, while not readily quantifiable, were found to be sufficient to guide both field mapping and image classification efforts to attain consistency in the level of resolution and detail of maps produced throughout the NROC site.

Methods for Extracting Data

The previous studies cited earlier established the feasibility of procedures for extracting data useful for reserve management tasks. The challenge of the present study was to refine and apply those methods to the site-specific habitats and management objectives of the NROC site. The task before us was to discover to what extent ADAR-based mapping methodologies pioneered earlier should be tailored to meet NROC's specific needs.

To address this question we defined a small subsection of the reserve to map initially as a way of working out site-specific methodologies that would best achieve NROC's mapping and monitoring needs. This process enabled us to standardize specific methods before proceeding with full-scale efforts to map the entire site. We chose Moro Canyon as our initial mapping site because it is an area that is relatively well known to the reserve managers and because it has fairly distinct geographic boundaries. Its size (1,720 acres) also makes it amenable to management as a relatively discrete unit. Preliminary ground reference data were developed through a site visit by a field biologist who mapped the site using categories modified from the adopted County of Orange classification scheme (Jones & Stokes, 1993). Following production of the first field map, the field biologist and the ADAR image interpretation technician visited the field together to become familiar with the characteristics of habitat types onsite. The field map was then used as ancillary data in the interactive "heads-up" procedure for classifying the ADAR image data. (For a detailed discussion of the "heads-up" classification method, see Brewster et al., 1999.)

The resulting, first-generation map of El Moro Canyon was then jointly critiqued by members of the team including the reserve manager. It was decided that a second field visit by the field biologist was warranted with several mapping goals in mind:

- ~ To refine the boundaries and reduce the size of map polygons in an effort to achieve higher data resolution through smaller mapped units;
- ~ To adhere more closely to adopted County of Orange categories, with some exceptions;
- ~ To clearly discriminate between scrubland-grassland ecotones;
- ~ To identify invasive plant stands according to species;
- ~ To discriminate between oak, sycamore and willow riparian scrub woodland, and forest habitats;

Following a second field visit and additional refinements, the map for Moro Canyon was finalized. The team then turned its attention to the remainder of the project area. Once the methodological groundwork for image interpretation was established through the Moro Canyon mapping exercise, mapping for other areas could be accomplished primarily through interpretation of the ADAR imagery with relatively little spot-checking of questionable vegetation types in the field. Based on the project team determined to apply the following specific methodologies in mapping the entire NROC site.

Habitat mapping, both in the field and from ADAR imagery, would adhere to the adopted County of Orange (Jones & Stokes, 1993) classification system, including classification decision rules as defined in Jones & Stokes, with some exceptions as noted below. (A complete list of habitat types with decision rules is provided in Appendix B.)

1. The standard category for Bush Mallow Scrub (2.3.11) is to be applied where bush mallow (*Malacothamnus fasciculatus*) is the dominant species (>50% relative cover) or co-dominant with *Salvia mellifera*; this rule applies even where bush mallow's dominance is believed to be a post-fire response in areas where a different plant community existed in pre-fire conditions. (This decision is based on the premise that, although bush mallow dominance may be a post-fire succession stage, the stage may persist 15 to 20 years, or longer and should therefore be mapped in its current condition for monitoring and management purposes.)

   Because of the prevalence of Bush Mallow, in cases where Bush Mallow occurs as a sub- or co-dominant (>20%) but in patches that are too small to map, a mixed class is to be applied.

   Examples of mixed classes include:

   1. Scrub/Chaparral Ecotone & Bush Mallow Scrub (3.1/2.3.11)
   2. Sagebrush-Buckwheat Scrub & Bush Mallow Scrub (2.3.1/2.3.11)
   3. Mixed Scrub/Grass Ecotone & Bush Mallow Scrub (2.8.5/2.3.11)

3. Patches of exotic invasive species (>30%) would be classified as Ruderal Grassland (4.6) and would be further delineated according to dominant species in an overlay map (e.g., Mustard, Artichoke Thistle).

4. In cases where *Rhus integrifolia* is found within coastal sage scrub at less than 20% cover, it should be considered a component of the scrub community. Where Rhus is 20% to 30% cover within sage scrub, the area should be mapped as Coastal Sage Scrub/Chaparral ecotone (3.1). In areas where *Rhus* patches reach >50% cover they should be mapped as Toyon/Sumac Chaparral (3.12).

With these decision rules established, the team embarked on developing a classified map for the entire coastal subregion of the NROC reserve.

Data Structure and Management Applications

As suggested earlier, a major decision point in developing appropriate methodologies was the decision to employ the previously established vegetation classification system (developed in Jones and Stokes and adopted by the County of Orange as its standard). Although the team determined that adherence to the Jones and Stokes scheme was, in the long-run, prudent, there were also persuasive reasons for considering alternatives. For example, during the initial mapping of Moro Canyon, it became apparent that bush mallow was abundant and nearly ubiquitous throughout the study area (with a few exceptions), regardless of the underlying plant community. Because bush mallow's current abundance is believed to be a successional response to fire, its presence raised the question of how to treat bush mallow and other post-fire habitat conditions in the mapping process.

Additionally, consideration of the anticipated management activities in the reserve suggests that future monitoring will seek to focus on features that manifest habitat disturbance in various forms (in addition to fire) and that these features are not always directly related to the plant community classifications assigned by using the modified Jones and Stokes system. The system is not sufficient for describing many of the disturbance-related effects that management is interested in monitoring. Its strictly botanical categories limits its effectiveness for mapping and monitoring habitat *quality*, as distinct from habitat *type* and *quantity*.

In addressing these issues, and in light of the project's fundamental premise that the resulting map product must be designed to serve the user's needs, the technical team recognized that the mapping effort must necessarily address additional tasks that go much farther than mere map-making. These tasks include designing a data structure that accommodates mapping and monitoring of habitat quality (in its multiple pertinent manifestations) and also designing a map-based monitoring system that will be operational in the lab and in the field to complement management activities. The baseline GIS vegetation map that is the product of this work is thus viewed as the central component of a future hardware/software/data configuration comprising a mapping and monitoring system. As the result of extensive deliberation, the team determined that the accompanying data structure for this system should include, at the outset, two distinct GIS files. The first is the originally conceived product of this project, a data base of existing plant communities classified according to modified Jones and Stokes botanical categories. This file will assume the traditional role of baseline botanical data. The second is an accompanying data layer termed the "management overlay" which identifies disturbance features such as roads and trails, patches of exotic weedy species, areas of soil disturbance and edge effects. Some of these features are also indicated in the baseline map to the extent that the adapted categories identify them (e.g., the Jones and Stokes system includes general categories for "Roads" and "Ruderal" features). But the management overlay will further delineate subcategories and attributes of these and other disturbance conditions.

The management overlay is intended to be used as a monitoring record, or "scratch pad", to record interim changes in habitat quality as they are monitored either opportunistically or through performance monitoring related to a specific management program. At the time of this writing it is anticipated that the overlay file will be made readily accessible in the field for real-time (or near real-time edits through a hand held computer (palm pilot) and/or wireless internet connecting device[2]. Changes to the underlying botanical data base (baseline layer) will be made only infrequently, perhaps on an annual cycle or less, when periodic monitoring intervals or management programs have terminated. In this way the baseline data will be protected from spurious, accidental or transitory edits and changes, while the management overlay provides a serial record of interim habitat quality changes and monitoring methods. Moreover, additional overlays can be produced as "scratch pads" for multiple monitoring purposes. The ability to create multiple and concurrent working map files will facilitate and (it is hoped) encourage research activities and related hypothesis-based management activities within the reserve.

The importance of hypothesis-based monitoring is a fundamental assumption inherent in the data structure assembled for this project. In the case of bush mallow, for example, the technical team hypothesizes that bush mallow will be succeeded over time as fire recovery continues. The implied hypothesis is that polygons mapped in the base layer as Bush Mallow Scrub (category 2.3.11) will gradually decrease in size and number. This will be replaced with a concurrent increase in Sagebrush-Buckwheat Scrub (2.3.1) or the Mixed Scrub (2.3.10) polygons. The progression of these changes, and the validity of the hypothesis, can be tracked using a "management overlay" file focused on bush mallow. Notable stages in this succession can be integrated periodically into the permanent data base layer when they reach a scale of significance at the landscape-level.

Next Steps

Production of an up-to-date data base of plant communities in the NROC coastal subregion provides the foundation for a monitoring system tailored to the reserve's research and management activities. Accompanied by a preliminary "management overlay" GIS file depicting features related to habitat disturbance, and the emergence of capabilities to carry real-time GIS into the field, development of this new data set initiates operation of a digital monitoring system that takes full advantage of remote sensing, GIS and wireless technologies. The full system will require further steps to tailor the software-user interface in a manner that facilitates easy access and editing of data by field personnel and the software-hardware interface to provide tools tailored for in-field applications. Related studies indicate that these steps are well within reach and easily achievable through continued efforts by researchers and NROC's management.

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[2]For a discussion of recent and ongoing applied research toward development of these in situ hand-held mapping capabilities, see Tsou et al., 2003.

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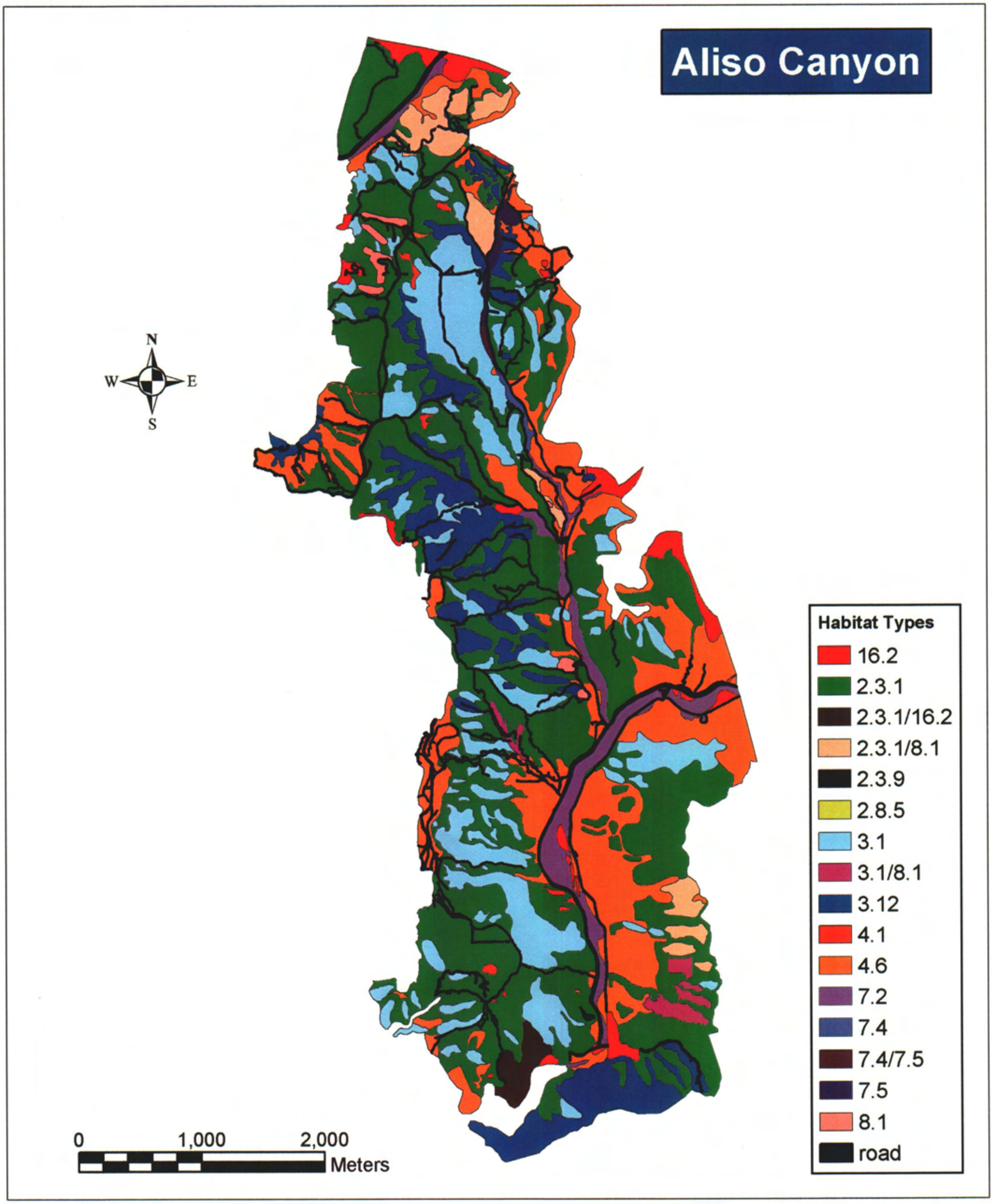
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2.3.1/16.2
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2.3.9
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3.12
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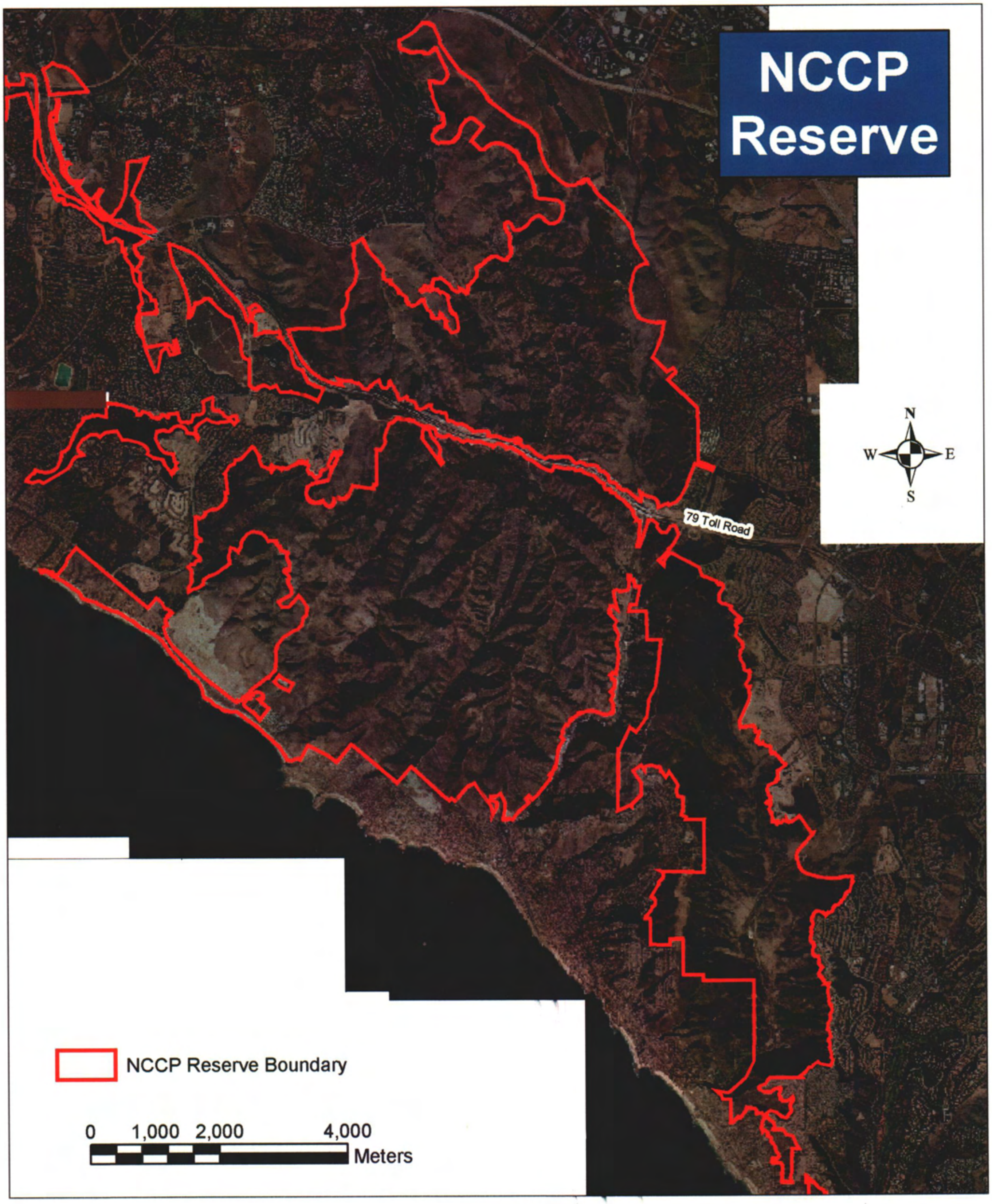
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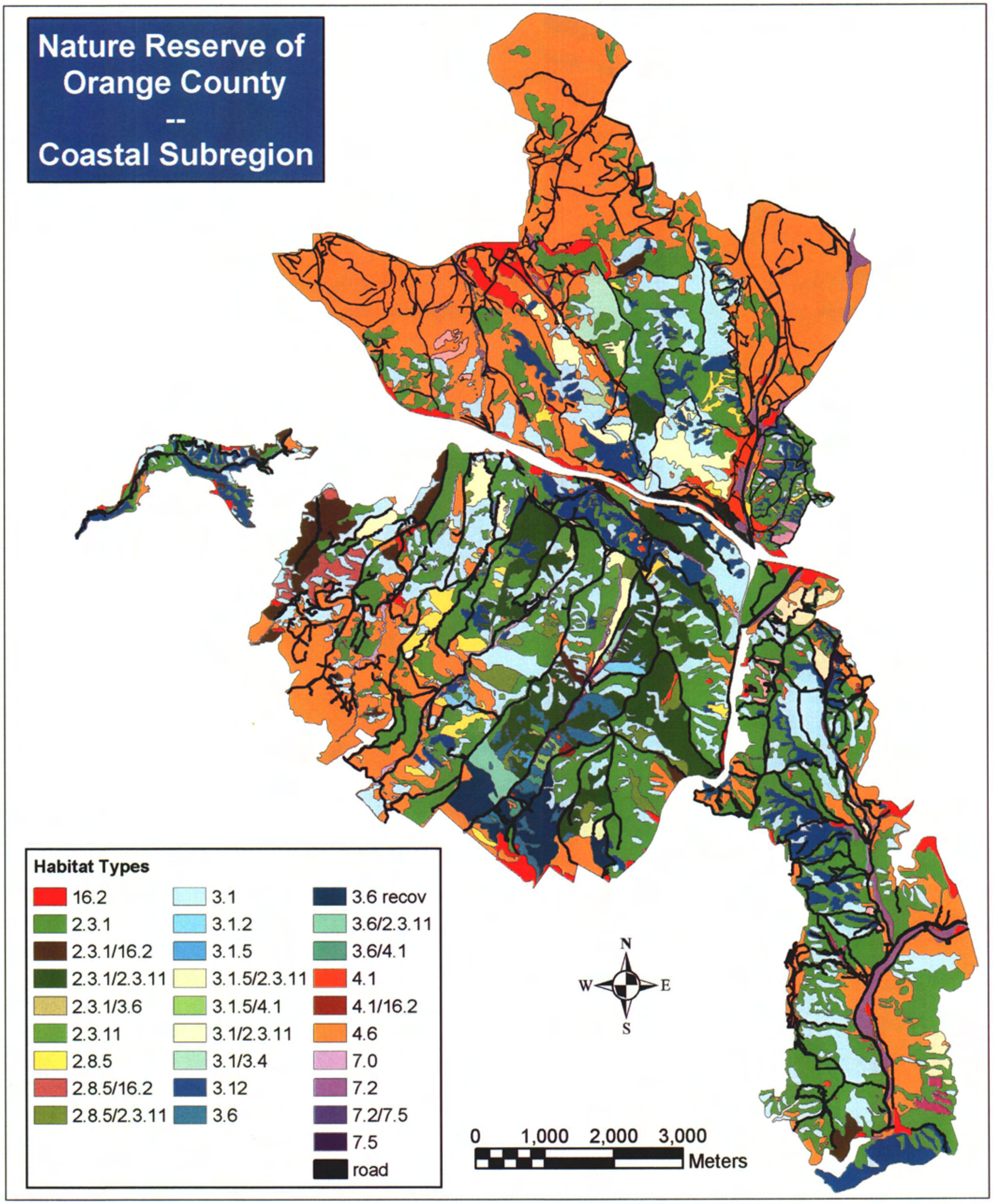
Nature Reserve of Orange County
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Coastal Subregion
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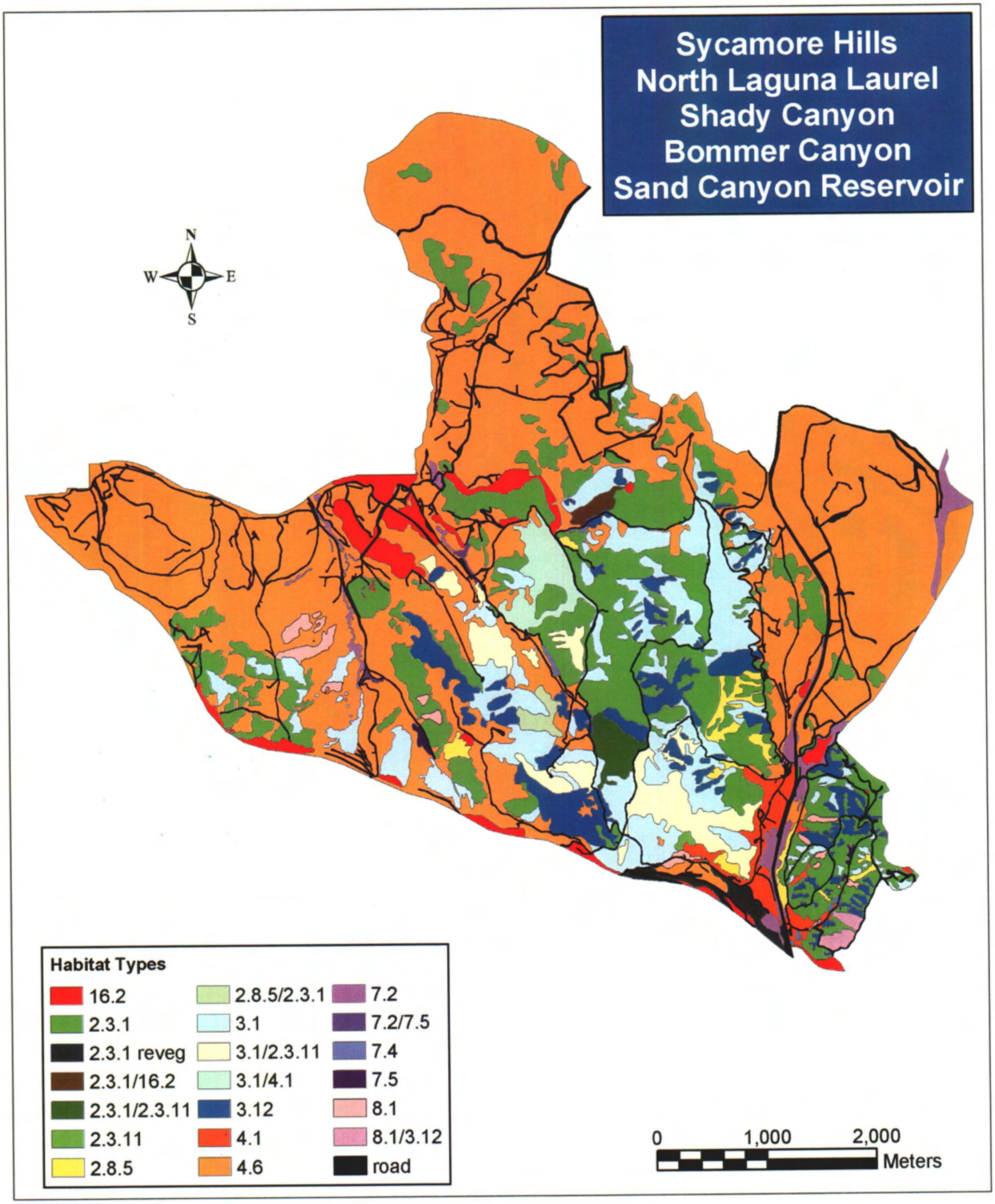

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North Laguna Laurel
Shady Canyon
Bommer Canyon
Sand Canyon Reservoir
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Habitat Types
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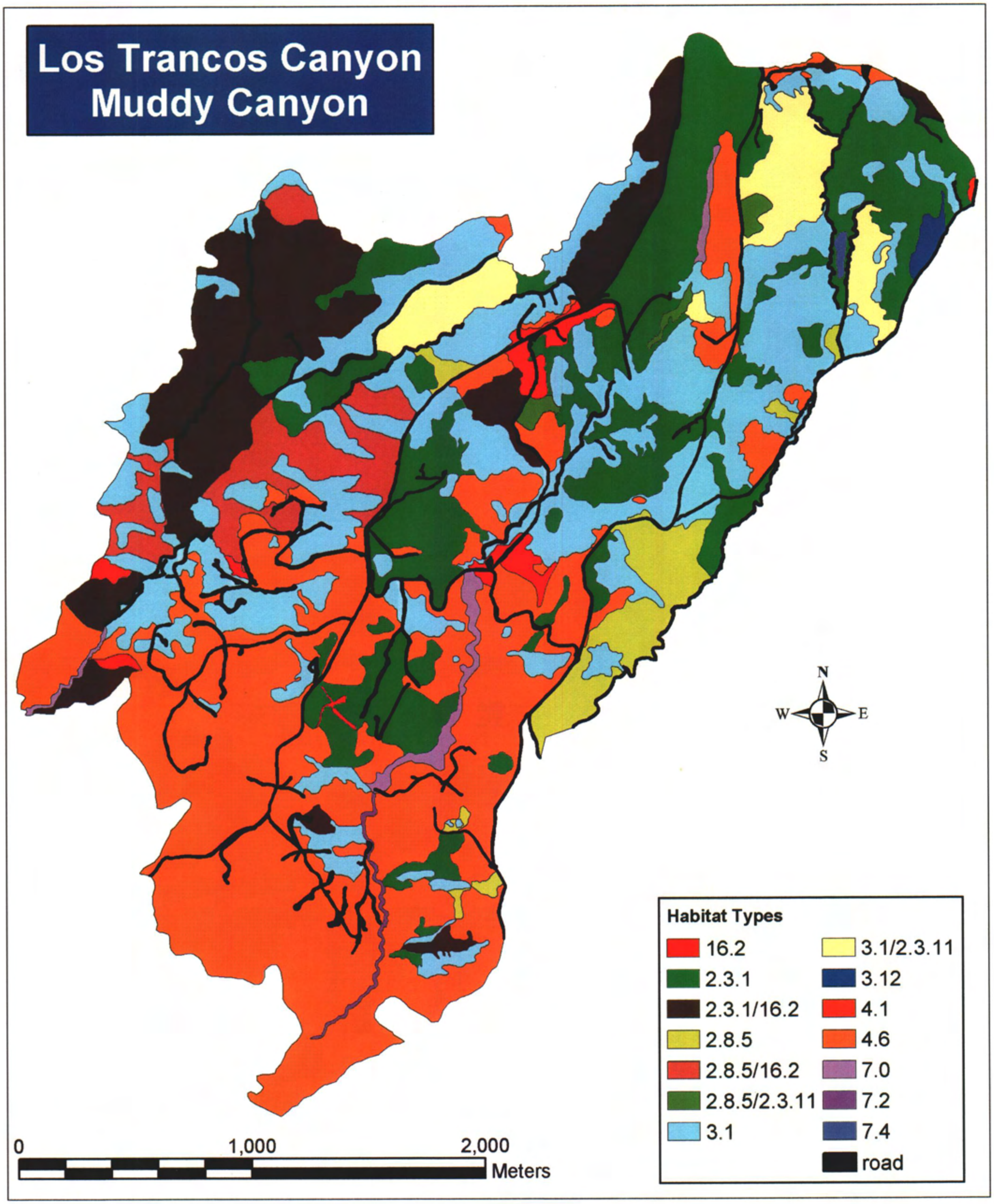

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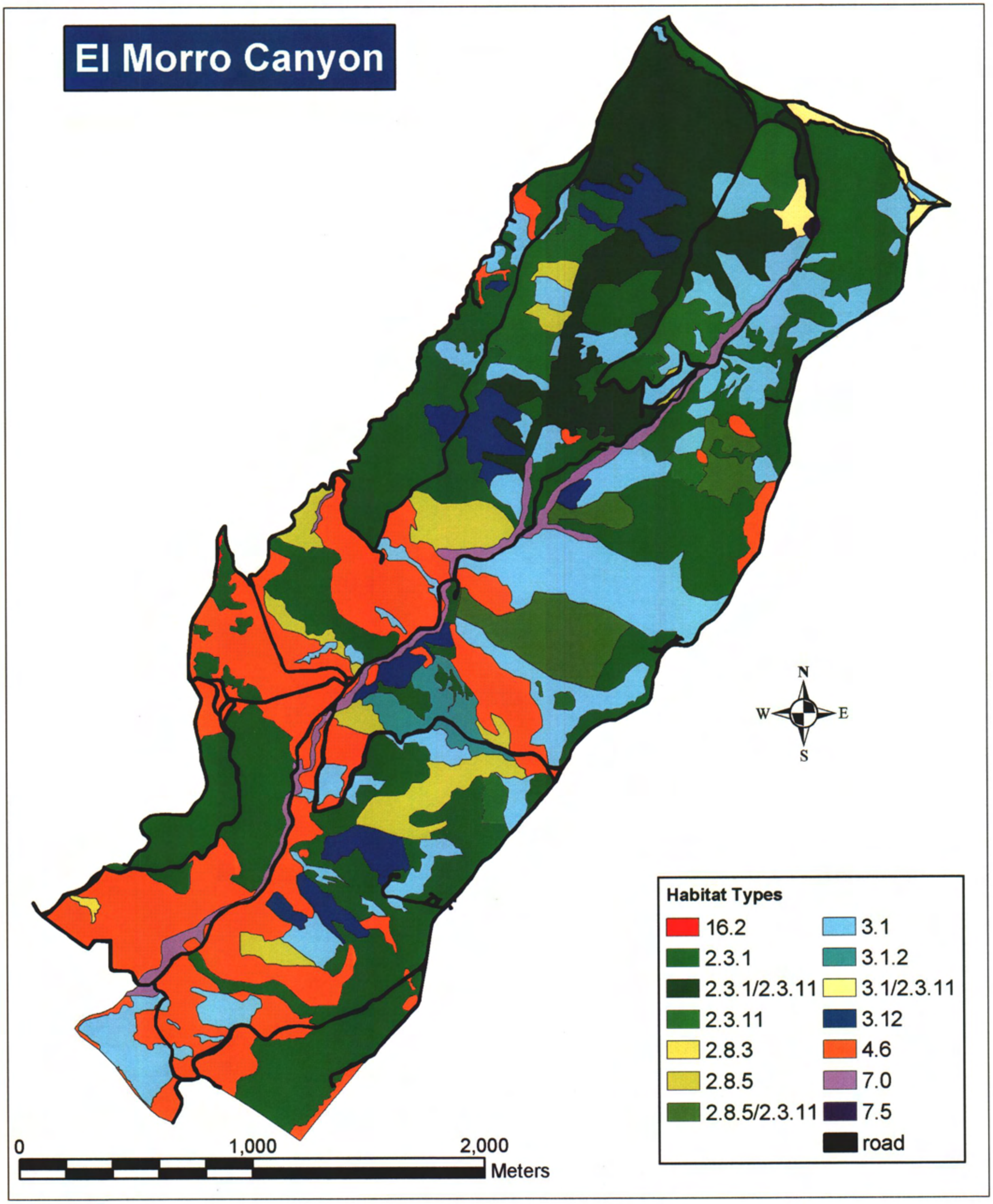
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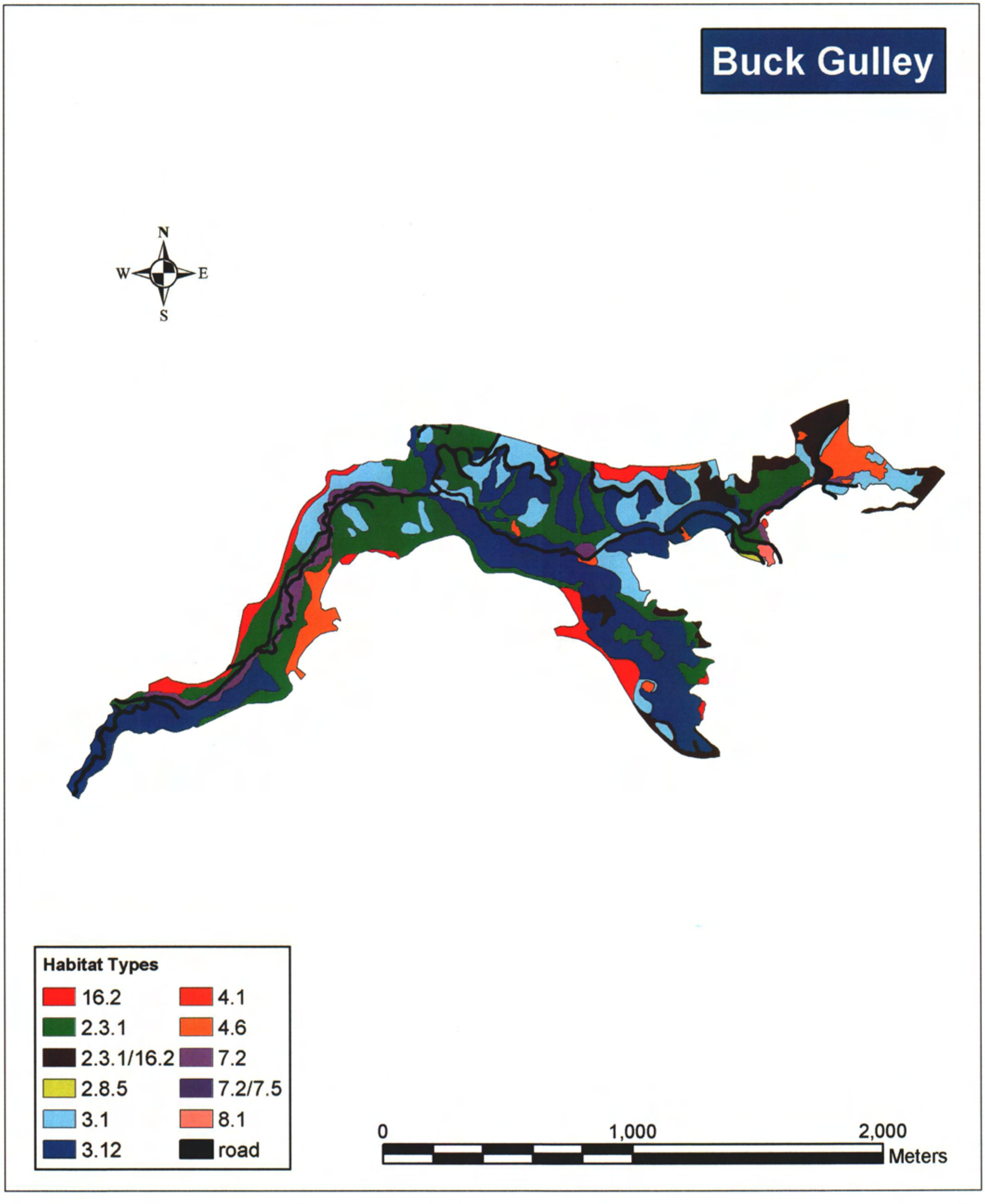
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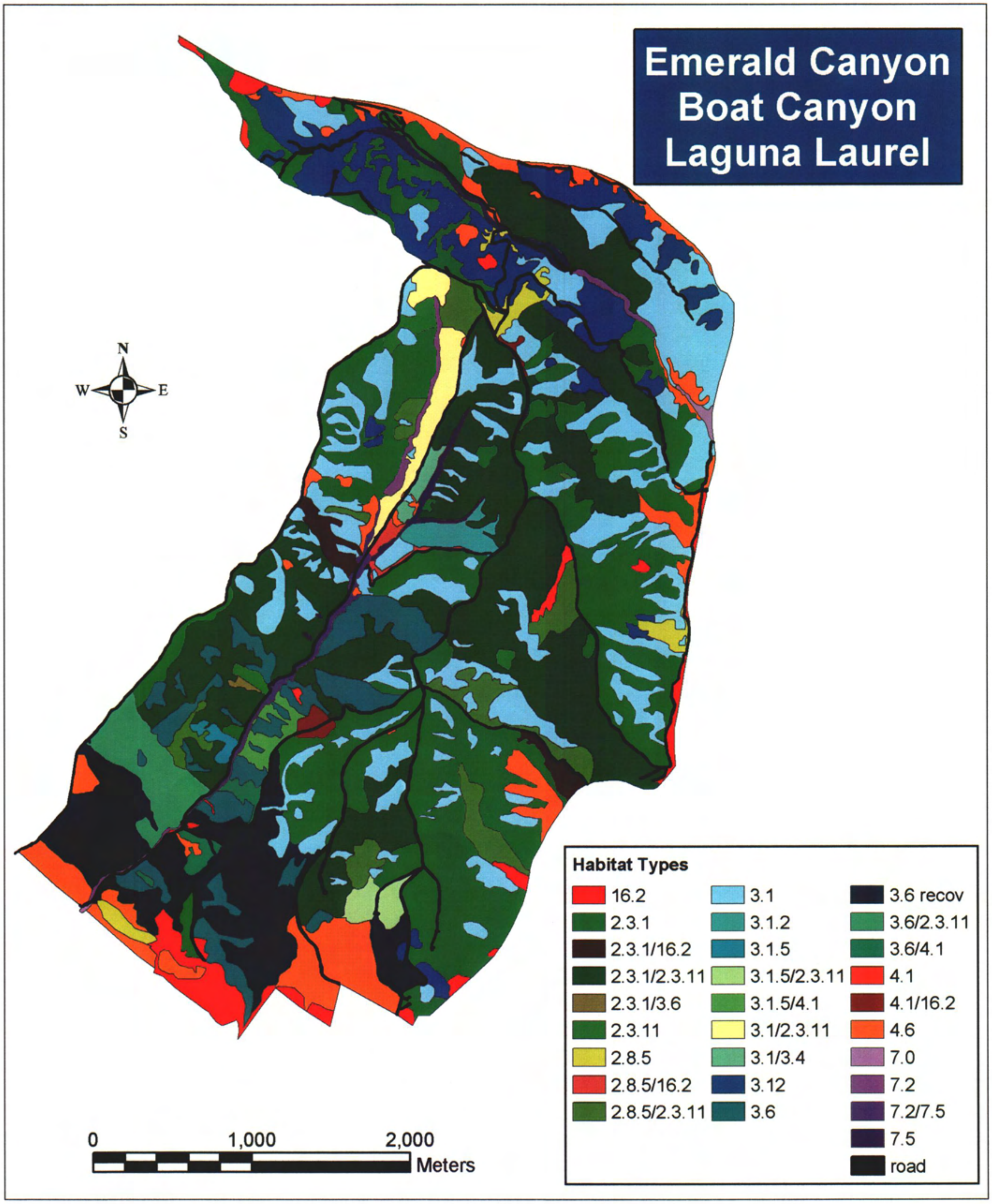
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Appendix A

ADAR Flight Parameters

ADAR FLIGHT PARAMETERS

ADAR System 5500

Dates Flown: 7/16/00 and 7/26/00

Number of Images captured:

Coastal	212
Inland	280
Total	492

Average Spatial Resolution: One meter per pixel

Desired overlap: 35% end and side

Aircraft Altitude: 7291' AGL

Average Frame Size: 1000 x 1500 meters @ 1 meter per pixel

Band	Bandwidth (nm)	Color
1	450 - 550	Blue
2	520 - 610	Green
3	610 - 700	Red
4	780 - 920	Near IR

Appendix B

Habitat Classifications and Decision-Rules

Habitat Types with Decision Rules

2.0 < 20% sumac
2.3.1. Sagebrush-Buckwheat Scrub (<5% grass)
2.3.9. Coyote Brush Scrub
2.3.11. Bush Mallow Scrub (>50% Bush Mallow)
2.8.3. Coastal Goldenbush-Grassland
2.8.5. Mixed Sage Scrub-Grassland (<20% scrub)

3.1. Scrub-Chaparral Ecotone/Sere (20-50% Sumac)
3.1.2. Chamise-Sage Scrub
3.1.5 Maritime Chaparral-Sagebrush
3.6. Maritime Chaparral
3.12. Toyon-Sumac Chaparral (>50% sumac)

4.1. Annual Grassland
4.6. Ruderal Grassland (>30% thistle or mustard)
8.1. Coast Live Oak Woodland
16.2. Human Disturbed Areas

Mixed classes (>20% of second class)

3.1./2.3.11. Scrub-Chaparral Ecotone & Bush Mallow Scrub
3.1./3.4. Scrub-Chaparral Ecotone & Ceanothus Chaparral
2.3.1./2.3.11. Sagebrush-Buckwheat Scrub & Bush Mallow Scrub
2.3.1./3.6. Sagebrush-Buckwheat Scrub & Maritime Chaparral
2.3.1./8.1. Sagebrush-Buckwheat Scrub & Coast Live Oak Woodland
2.3.1./16.2. Sagebrush-Buckwheat Scrub & Other Disturbed Areas
2.8.5./2.3.11. Mixed Sage Scrub-Grass Ecotone & Bush Mallow Scrub
2.8.5./16.2. Mixed Sage Scrub-Grass Ecotone & Other Disturbed Areas
3.1.5./2.3.11. Maritime Chaparral-Sagebrush & Bush Mallow Scrub
3.1.5./4.1. Maritime Chaparral- Sagebrush & Annual Grassland
3.6./2.3.11. Maritime Chaparral & Bush Mallow Scrub
3.6/4.1. Maritime Chaparral & Annual Grassland
4.1/16.2. Annual Grassland & Other Disturbed Areas

Riparian Habitats

7.2. Willow Riparian Scrub
7.3. Mulefat Scrub
7.4. Sycamore Riparian Woodland
7.5. Coast Live Oak Riparian Forest