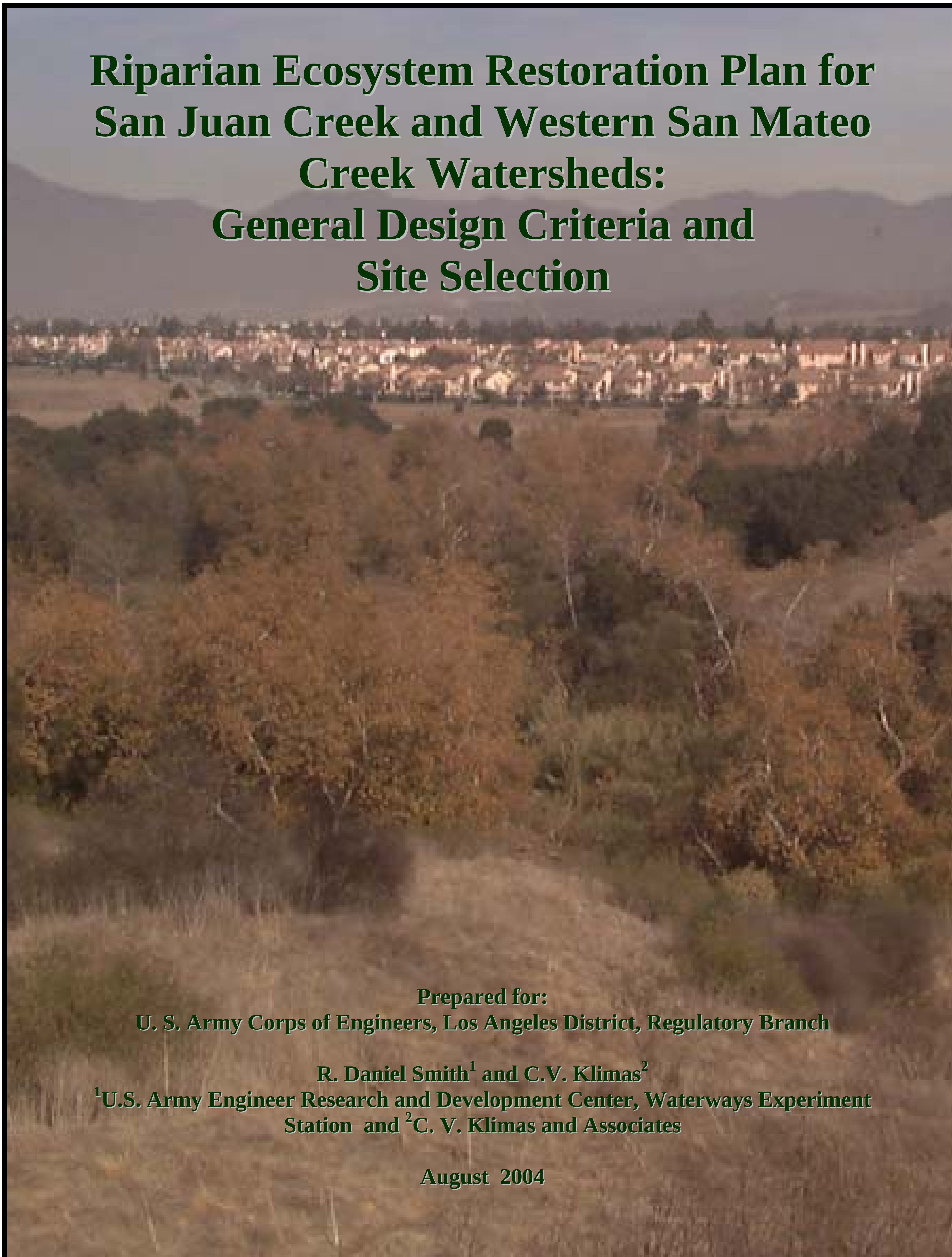

Riparian Ecosystem Restoration Plan for San Juan Creek and Western San Mateo Creek Watersheds: General Design Criteria and Site Selection

Prepared for:
U. S. Army Corps of Engineers, Los Angeles District, Regulatory Branch

R. Daniel Smith[1] and C.V. Klimas[2]
[1]U.S. Army Engineer Research and Development Center, Waterways Experiment Station and [2]C. V. Klimas and Associates

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Executive Summary

The Los Angeles District Corps of Engineers - Regulatory Branch is developing a Special Area Management Plan (SAMP) for the San Juan Creek and Western San Mateo Creek watersheds in Orange County and portions of Riverside and San Diego Counties, California. The goal of the SAMP is to…"develop and implement a watershed-wide aquatic resource management plan and implementation program, which will include preservation, enhancement, and restoration of aquatic resources, while allowing reasonable and responsible economic development and activities within the watershed-wide study area". Several studies have been conducted in support of the SAMP including a watershed-wide delineation of aquatic resources using a unique planning level delineation procedure, and a baseline assessment of riparian ecosystem integrity. This report describes a planning tool intended for use with the baseline assessment to help identify riparian ecosystem restoration opportunities within the study area.

The objective of the Watershed Restoration Plan is to facilitate development of an aquatic resources reserve program in the San Juan Creek and Western San Mateo Creek watersheds through an evaluation of the potential for restoring a riparian ecosystem. The general approach to achieving this objective is to classify each riparian area in terms of its geomorphic characteristics, characterize the current condition of each riparian area, assign a general restoration design template, and then estimate the level-of-effort necessary to meet the design target. The approach allows consideration of restoration effectiveness at both the riparian ecosystem and drainage basin spatial scales, and provides a mechanism for testing the effectiveness of various combinations of restoration actions, such as concentrating restoration efforts on all degraded reaches in a drainage basin, versus giving priority to restoration of reaches where the greatest functional improvement can be attained per unit effort.

All of the options for testing and analyzing restoration options and scenarios are implemented in the context of a geographic information system. Thus, the information presented herein constitutes a flexible planning tool that is adaptable to changes in on-the-ground conditions, data quality, project priorities, and similar eventualities.

Contents

1.0 Introduction and Background 1

2.0 Objectives and Assumptions....3

3.0 Study Area 5

4.0 Methods....9

4.1 General Approach and Definitions....9

4.2 Geomorphic Zones 12
4.2.1 Geomorphic Zone 1: Riparian areas in v-shaped valleys with predominantly bedrock control 13
4.2.2 Geomorphic Zone 2: Small floodplains and terrace fragments in mountain and foothill valleys, where meander belt formation is restricted by lateral impingements of alluvial fans, colluvium, and boulder bars 14
4.2.3 Geomorphic Zone 3: Boulder-dominated floodplain and terrace complexes....15
4.2.4 Geomorphic Zone 4: Alluvium of meandering channels within broad lowland valleys 16
4.2.5 Geomorphic Zone 5: Large alluvial valleys....17

4.3 Restoration Templates....18
4.3.1 Natural Channel Template 20
4.3.2 Incised Channel Template....21
4.3.3 Constrained Channel Template....22
4.3.4 Aggraded Channel Template 23
4.3.5 Engineered Channel Template....24
4.3.6 Restoration Impractical....25

4.4 Level of Effort....26
4.4.1 Level of Effort None....26
4.4.2 Level of Effort Light Planting....26
4.4.3 Level of Effort Light Earthwork / Heavy Planting 27
4.4.4 Level of Effort Moderate Earthwork / Heavy Planting 27
4.4.5 Level of Effort Heavy Earthwork / Heavy Planting 27
4.4.6 Level of Effort Impractical 28

4.5 Restoration Simulations 28

5.0 Results and Discussion 31

5.1 Riparian Reach Classification, Template, and Level of Effort Assignments....31

5.2 Conceptual Restoration Design....34

5.3 Restoration Simulations 35

6.0 Literature Cited 50

Appendix A: ArcView Theme and Images, Spreadsheet, and Report Files.....................................56

Appendix B: PTYPE for the Preliminary digital geologic map of the Santa Ana
30' x 60' quadrangle, Southern California, Version 1 57

Figures

Figure 1. San Juan Creek and Western San Mateo Creek watersheds study area boundaries..........5
Figure 2. Geology of the San Juan and Western San Mateo watersheds...7
Figure 3. Relationship of riparian reaches, local drainage areas, and drainage basins.....................10
Figure 4. Illustration of riparian ecosystem geomorphic surfaces...11
Figure 5. Generalized representation of landscape settings associated with geomorphic zone assignments 12
Figure 6. General form of Geomorphic Zone 1 and view of typical reach......................................13
Figure 7. General form of Geomorphic Zone 2 and view of typical reach......................................14
Figure 8. General form of Geomorphic Zone 3 and view of typical reach......................................15
Figure 9. General form of Geomorphic Zone 4 and view of typical reach......................................17
Figure 10. General form of Geomorphic Zone 5 and view of typical reach....................................18
Figure 11. Typical pre- and post-restoration conditions of riparian reaches assigned to the Natural Template 21
Figure 12. Typical pre- and post-restoration conditions of riparian reaches assigned to the Incised Template...22
Figure 13. Typical pre- and post-restoration conditions of riparian reaches assigned to the Constrained Template 23
Figure 14. Typical pre- and post-restoration conditions of riparian reaches assigned to the Aggraded Template...24
Figure 15. Typical pre- and post-restoration conditions of riparian reaches assigned to the Engineered Template 25
Figure 16. Geomorphic Zone assignments for riparian reaches 31
Figure 17. Restoration Template assignments for riparian reaches...32
Figure 18. Level of Effort assignments for riparian reaches 33
Figure 19. Normalized baseline hydrology integrity indices for riparian reaches...........................36
Figure 20. Normalized baseline water quality integrity indices for riparian reaches 37
Figure 21. Normalized baseline habitat integrity indices for riparian reaches 38
Figure 22. Increase in hydrology integrity index increase for riparian reaches after simulated restoration..40
Figure 23. Increase in water quality integrity index for riparian reaches after simulated restoration..41
Figure 24. Increase in habitat integrity index for riparian reaches after simulated restoration..42
Figure 25. Increase in hydrology integrity index / level-of-effort units for riparian reaches after simulated restoration..43
Figure 26. Increase in water quality integrity index / level-of-effort units for riparian reaches after simulated restoration..44
Figure 27. Increase in habitat integrity index / level-of-effort units for riparian reaches after simulated restoration..45
Figure 28. Increase in hydrology integrity index after simulation restoration in riparian ecosystems and uplands in the drainage basin of the riparian reach...............................46
Figure 29. Increase in hydrology integrity index after simulation restoration in riparian ecosystems and uplands in the drainage basin of the riparian reach...............................47
Figure 30. Increase in hydrology integrity index after simulation restoration in riparian ecosystems and uplands in the drainage basin of the riparian reach...............................48

Tables

Table 1. New scores assigned to riparian reach scale indicators based on Restoration Template ...29

Table 2. Dimensions of geomorphic features measured in least-disturbed riparian reaches in the study area 35

Table 3. PTYPE descriptions for Preliminary Digital Geologic Map of Santa Ana 58

1.0 Introduction and Background

The Los Angeles District Corps of Engineers - Regulatory Branch is developing a Special Area Management Plan (SAMP) for the San Juan Creek and Western San Mateo Creek watersheds in southern Orange, western Riverside, and northern San Diego Counties, California. The SAMP is being conducted in coordination with the existing and proposed amendment to the Southern Subregion Natural Community Conservation Plan (NCCP). The goal of the SAMP is to…"develop and implement a watershed-wide aquatic resource management plan and implementation program, which will include preservation, enhancement, and restoration of aquatic resources, while allowing reasonable and responsible economic development and activities within the watershed-wide study area" (U.S. Army Corps of Engineeers Los Angeles District 1999).

The following studies were completed in support of the SAMP: a watershed wide delineation of aquatic resources using a unique planning level delineation procedure (Lichvar 2000); and a baseline assessment of riparian ecosystem integrity (Smith 2001). The baseline assessment was conducted using the following approach. Riparian ecosystems were defined as linear corridors of variable width along perennial, intermittent, and ephemeral streams exhibiting distinctive geomorphic features and vegetation communities in response to the periodic exchange of surface and ground water between the stream channel and adjacent areas. Due to the large size of the study area, inherent variability of riparian ecosystems, and differential nature of historical impacts to riparian ecosystems, one of the first tasks in the baseline assessment was to delineate the riparian ecosystems into relatively homogenous assessment units we called "riparian reaches." Riparian reaches were defined as discrete segments of the main stem, bankfull stream channel, and the adjacent riparian ecosystem that were relatively homogenous with respect to geology, geomorphology, channel morphology and substrate, vegetation communities, and cultural alteration. Each riparian reach was assessed using a suite of indicators that represent physical, chemical, and biological factors influencing riparian ecosystem integrity at the three spatial scales: the riparian reach; the local drainage area (i.e., the area contributing to tributary, groundwater, and overland flow that directly enters the riparian reach); and the drainage basin (i.e., the area contributing to main stem inflow from upstream of a riparian reach).

Indicators were scaled to a reference condition and then combined into hydrologic, water quality, and habitat integrity indices.

Information from the delineation and baseline assessment was being used in two additional SAMP studies. The first is an alternatives analysis in which several proposed alternatives were analyzed to identify the level of impact each alternative would have on aquatic resources in the study area. The second is the Watershed Restoration Plan, the subject of this report. In addition, information from the baseline assessment was also incorporated into a recent overview of resources and physical environments of the San Juan Creek and Western San Mateo Creek Watersheds, and their significance in the context of planning at the watershed and sub-basin scales (PCR et al. 2001).

2.0 Objectives and Assumptions

The objective of this project is to provide a planning tool that can be used to help devise an effective aquatic resources reserve program in the study area. Specifically, this tool will be used as part of an evolving planning process, where multiple restoration scenarios may need to be assessed in terms of their effects on riparian ecosystem integrity at the reach, sub-basin, and basin scales. Development of this planning tool involves two separate procedures. The first is the assessment of the restoration potential of each riparian reach in the study area, and the level of effort required to meet that restoration potential. The second is the assessment of the change in riparian ecosystem integrity that is expected to occur under various restoration scenarios. The second procedure is accomplished by using the baseline assessment approach to re-assess riparian ecosystem integrity using input parameters (i.e., indicator metrics) that reflect the postulated restored condition of riparian reaches. This approach relates reach-specific changes to riparian ecosystem function at multiple scales, and allows estimation of the basin-wide and sub-basin effects of a restoration action undertaken in a single reach.

In order to develop a practical planning tool that can be used as described above, we developed specific categories of "restoration potential" and "level of effort" that could be applied consistently to riparian reaches throughout the study area. Restoration potential refers to the level of restoration that is practical under existing conditions. It is defined in the context of extant, stable, and naturally functioning riparian ecosystems in the region, and focuses primarily on the geomorphic features and processes that determine the extent to which natural patterns of vegetation composition, structure, and diversity can be re-established and sustained. This perspective was applied to all riparian reaches in the study area, regardless of whether a particular location might be available or appropriate for restoration.

In the context of restoration potential we developed a set of general restoration guidelines that reflect a variety of specific practical considerations. For example, we assumed it was “impractical” to consider restoration options that involve carving new channels through non-alluvial substrates, or using fill material to build terrace systems within extensively eroded valley bottoms. However, manipulation of natural alluvial substrates to improve channel alignment or floodplain and terrace configurations is considered practical, reasonable, and feasible in most cases. Similarly, underground drainage systems and large concrete channels through heavily developed areas are generally regarded as impractical to restore, but some exceptions are made where these engineered features are small or non-functional, and traverse agricultural or recreational land. In no case do we consider removal of roads, buildings, or other significant infrastructure as a restoration option; however, changes in land use from agriculture, rangeland, or recreational areas to natural vegetation is included as a potential restoration tool.

In addition to "restoration potential" we also developed a simple, relative estimate of the resources required to restore a riparian ecosystem to its full potential. This level of effort estimate is included as an additional planning tool based on the assumption that there may be limited resources available for restoration, or limited potential sites available to offset certain types of impacts. Under these circumstances it may be useful to consider cost as a factor in the event that a variety of potential scenarios must be assessed for feasibility and efficacy. To that end, level- of-effort units are assigned to each riparian reach as a crude estimate of the relative construction and planting costs per unit area within the riparian ecosystem. The level of effort estimates do not include consideration of land purchase costs, the costs of upland restoration (e.g. conversion of rangeland to native vegetation) or similar/unforeseen factors that could substantially change the estimates.

The approach we have developed allows for the consideration of restoration effectiveness at several scales (i.e., riparian reach, local drainage area, and drainage basin). It also provides a mechanism for testing the effectiveness of various combinations of restoration actions, such as concentrating restoration efforts on all degraded reaches in a drainage basin, versus giving priority to restoration of reaches where the greatest functional increase can be attained per unit effort.

All of the options for testing and analyzing restoration options and scenarios are designed for application in the context of a geographic information system and spreadsheets. Thus, the information presented here constitutes a flexible planning tool that is adaptable to changes in on-the-ground conditions, data quality, project priorities, and similar eventualities.

3.0 Study Area

The study area encompasses a 197 mi^2 are located in southern Orange County and small portions in western Riverside and northern San Diego Counties, California. It includes all the San Juan Creek watershed and the western portion of the San Mateo Creek outside of the Camp Pendleton Marine Corps Base (Figure 1). Headwaters of both creeks originate in the Santa Ana Mountains or Coastal Hills Ecological Subsections of the California South Coast Ecoregion (Miles and Goudy 2003). Streams in the study area generally drain toward the south and west.

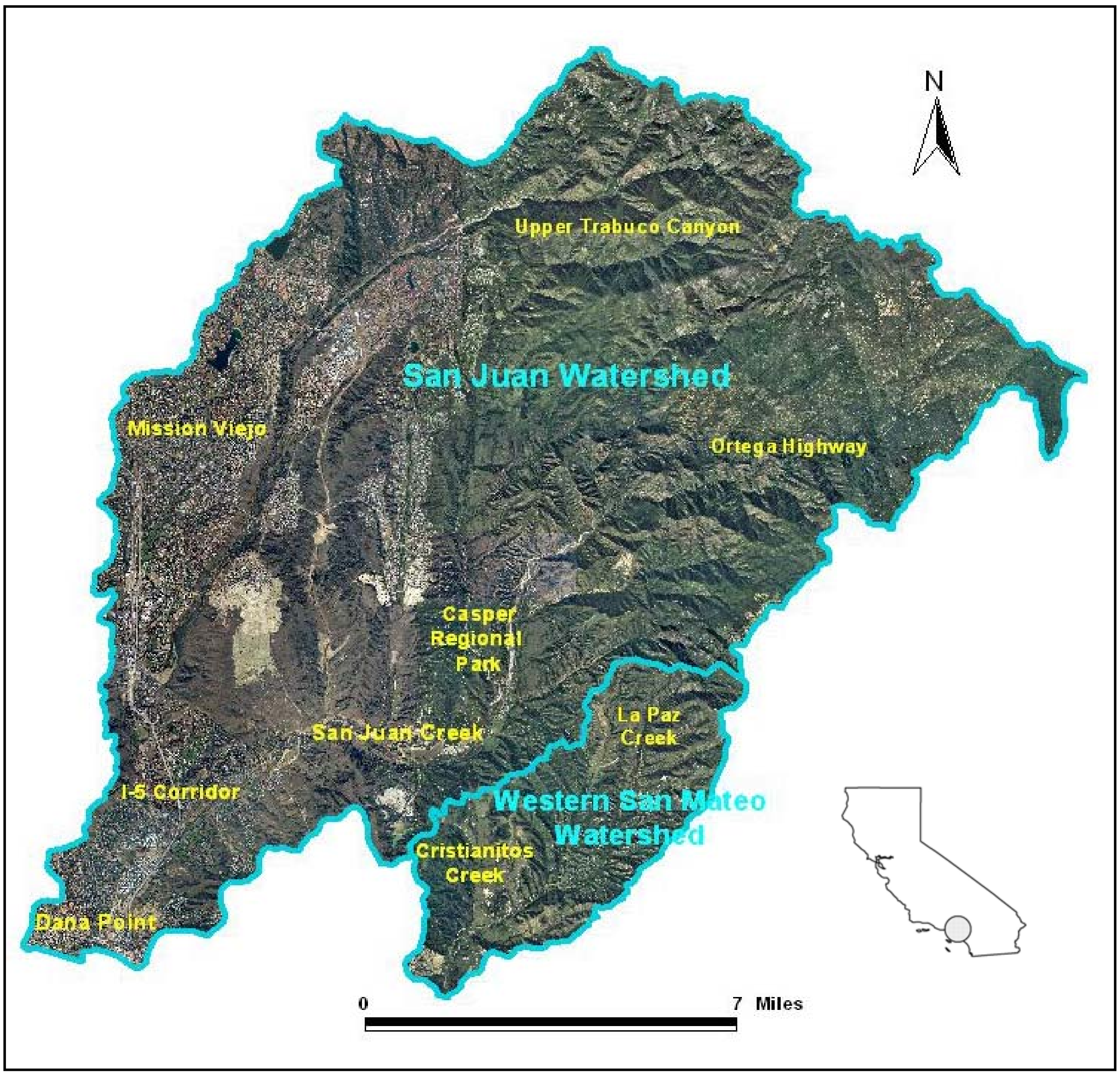

Figure 1. San Juan Creek and Western San Mateo Creek watersheds study area boundaries

Geology in the vicinity of the study (Figure 2) is complex, reflecting crustal compression and faulting, uplift and subsidence, volcanism, and multiple periods of erosion and deposition in both marine and alluvial environments (Morton et al. 1976). Soils reflect the various parent materials and topographic settings, and are similarly diverse (Wachtell 1978). A recent report summarizing physical and biological conditions within the study area integrates these complexities into three principal "terrains" including the "clayey" terrains of the western portion of the watershed, "sandy-silty" terrains of the central drainages, and "crystalline" terrains of the eastern part of the area (PCR et al. 2001). At this gross level of classification, a number of generalizations can be made that have ecological significance. For example, runoff is likely to be most rapid in clayey terrains, while infiltration rates and erodibility are likely greatest in sandy terrains. The silty-sandy terrains in the central part of the study area tend to have lower drainage densities than the other areas, and tributary valleys are often without well-defined surface connections to main stem channels. The PCR et al. (2001) report includes extensive discussion of the implications of geologic setting on factors such as hydrology, sediment movement, and water quality, and the reader is referred to that document for further details.

Although the "terrains" described above have relevance to the characteristics of riparian ecosystems in the study area, the geomorphic classification system we use (see next section) more directly reflects the distribution of alluvial and colluvial surfaces. The geologic mapping of Morton and Miller (1981) and Morton et al. (1999) shows extensive Quaternary alluvium within the study area, including high Pleistocene terraces as well as low terraces and floodplains within active (or recent) meander belts (Figure 2). Within the mountains and foothills, landslide areas that have contributed large amounts of sediment and debris directly to stream channels occur intermittently along most streams, and the larger landslides are mapped (Morton and Miller 1981).

Natural vegetation in the study area varies according to landscape position, aspect, soils, and elevation (CCC 2001). Upland slopes in the mountains are characterized by mixed chaparral communities, which give way to coastal sage-scrub in the foothills. Lower slopes and high terrace settings often are dominated by oak woodlands that typically include a variety of associated species such as big leaf maple and poison oak. Lower terraces characteristically support sycamore, with cottonwood common in some areas. Floodplains and streambanks generally are dominated by sycamore, willow, and mulefat. Prior to European settlement,

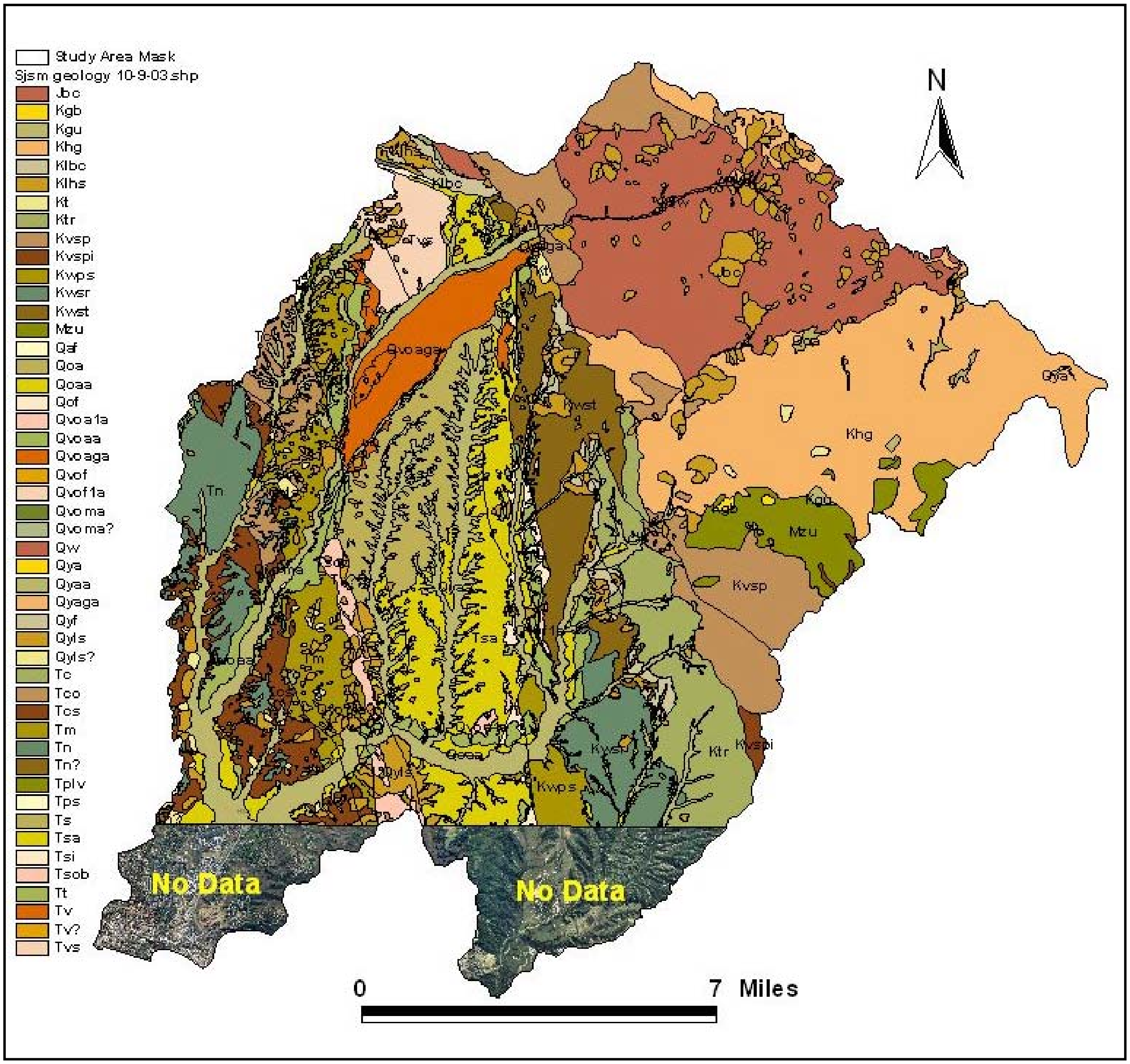

Figure 2. Geology of the San Juan and Western San Mateo watersheds (Morton et. al. 1999)

native grasslands occurred in the coastal hills and valleys (Heady 1977). Within these general community patterns, a variety of variations may occur. For example, where lower stream terraces are predominantly droughty sands and gravels, coastal sage scrub species may replace or co-exist with sycamore and mulefat. Conversely, oaks and scattered sycamore sometimes extend far up steep valley walls in protected, north-facing drainages.

Historic and current land use patterns have significantly altered vegetation distribution and dominance patterns (CCC 2001). Early Spanish explorers observed that the Native American tribes in the region actively burned brushlands, but otherwise the indigenous people presumably had minimal impact on the landscape. However, with the establishment of Spanish missions and large ranches in the 18th century, wholesale changes to native vegetation and ecosystem processes began, and have continued to the present. The Spanish introduced irrigation, exploited timber resources, and cleared native vegetation mechanically and with fire to establish grazing lands. They also began the process of introducing European plant species to the landscape, and in particular replaced native grasslands with non-native species. In the mid-19th century, miners in search of gold, silver, and other minerals extensively worked the canyons of the upper watershed, in the process, cut trees for timbers and started large fires, which exposed the slopes to erosion and caused stream channels to receive excessive sediment loads and carry extreme flows during wet periods.

During the late 19th century and continuing to the present, the study area has undergone significant change. Much of the upper watershed was designated as National Forest, and other reserve and park systems were established. At the same time, ranching continued over the major part of the foothills, with ranchlands gradually being converted to housing tracts (CCC 2001). Extensive in-channel sand and gravel mining has likely contributed to deep incision of the lower reaches of several streams (PCR et al. 2001). At least 10 large floods occurred in coastal southern California watersheds during the 20th century, each with the potential to cause extensive sediment mobilization and redistribution. In particular, a major flood in 1969 that followed a decade after much of the eastern San Juan basin had burned is believed to have caused extensive sediment deposition and subsequent dramatic incision of downstream channels (PCR et al. 2001).

4.0 Methods

4.1 General Approach and Definitions

The assessment units used in this study were the riparian reaches designated during the baseline assessment of riparian ecosystems (Smith 2001). Adopting the riparian reach designations allowed us to assess the effects of proposed restoration actions on riparian ecosystem integrity using the same methods and criteria employed during the baseline assessment, and allowed us to take advantage of an extensive database of site and community characteristics recorded during the baseline assessment.

For this study, riparian reaches were defined as discrete, relatively homogenous segments of main stem stream channel and adjacent riparian ecosystem, with respect to geology, geomorphology, channel morphology, substrate type, vegetation communities, and cultural alteration (Figure 3). Associated with each riparian reach a local drainage area (i.e., the area contributing to tributary, groundwater, and surface flow directly to the riparian reach), and a drainage basin (i.e., the area contributing to main stem flow into the riparian reach) were identified. Land use and hydrologic characteristics were recorded for each of the local drainage areas as part of the baseline assessment. All of these factors were considered in assessment of the restoration options identified in this study. A total of 388 riparian reaches were designated within the study area.

In order to assess the restoration potential, each riparian reach was classified in terms of: its “geomorphic zone” (reflecting fundamental geomorphic characteristics under "equilibrium" conditions); a "restoration template" reflecting the extent to which the fundamental equilibrium condition could be re-established; and the “level of effort" necessary to achieve the conditions defined by the restoration template. Each riparian reach was classified in terms of geomorphic zone, restoration template, and level of effort during an initial basin-wide reconnaissance, with subsequent detailed field characterizations of 96 riparian reaches through the use of aerial photography, and review of detailed data collected during the baseline assessment study.

The terms used to describe geomorphic settings and restoration templates are defined below and largely reflect the usage of Dunne and Leopold (1978), Rosgen (1996), and/or Ritter (1986). However, some definitions have been framed in terms specific to the San Juan Creek and Mateo watersheds and the objectives of this study.

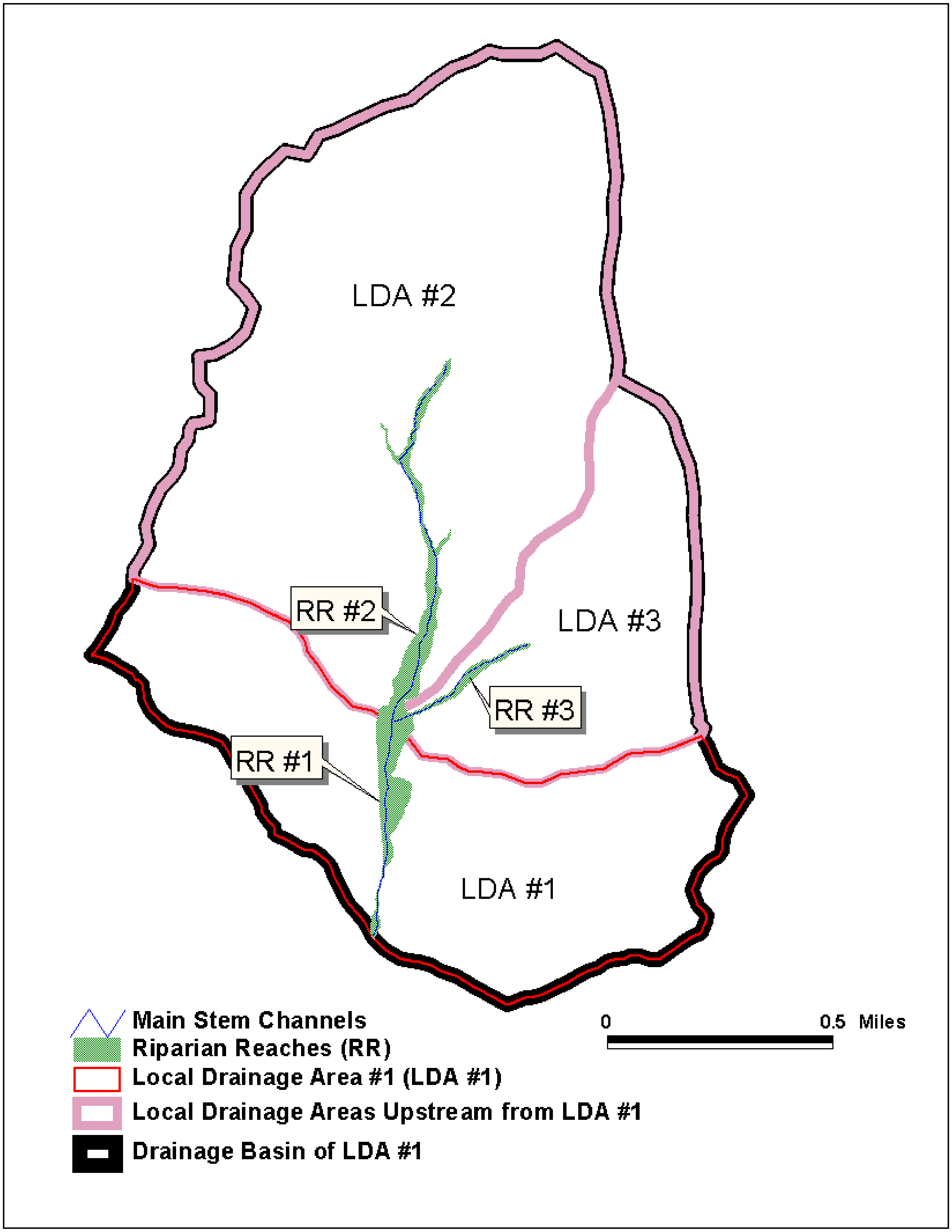

Figure 3. Relationship of riparian reaches, local drainage areas, and drainage basins

Bankfull Channel: The active stream channel is defined as the area inundated when the stream is at bankfull stage, which corresponds to the discharge at which most channel-forming processes occur (Figure 4). For most streams this discharge has a recurrence interval of approximately 1.5 years.

Floodplain: Technically, the floodplain is the valley floor level corresponding to the bankfull stage, but in fact various "floodplains" (e.g. 5-year, 10-year, etc.) include surfaces inundated at flow depths or frequencies that are of interest in a particular situation. For the purposes of this study the floodplain corresponds to the "floodprone area" as defined by Rosgen (1996). This is the area flooded when maximum channel depth is twice the maximum depth at the bankfull

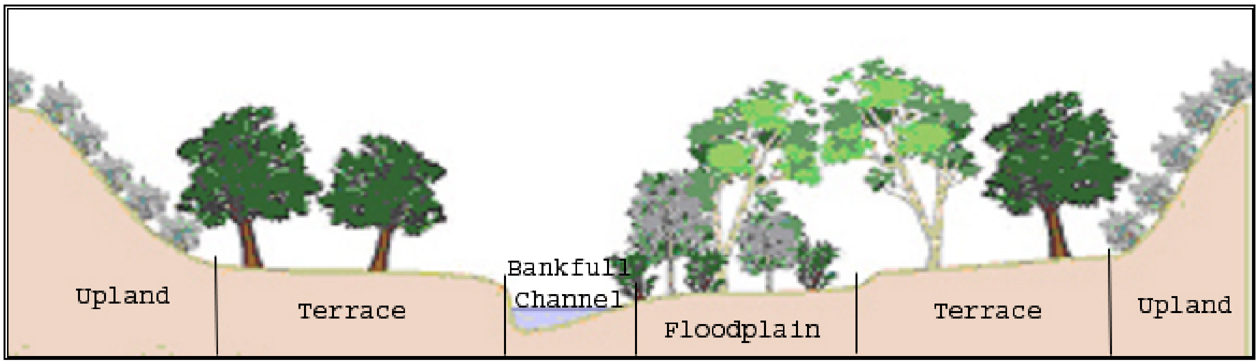

Figure 4. Illustration of riparian ecosystem geomorphic surfaces

stage. In coastal streams of southern California, the floodprone area usually includes most or all of the point bar deposits below the scarp rising to the lowest distinct terrace.

Terraces: Terraces are usually defined as former floodplains, although they also include flat surfaces carved by flowing waters, or the wave-cut surfaces of the marine terraces. For the purposes of this study, terraces (other than marine deposits) are alluvial features originally deposited as floodplains, but which now are situated above the floodprone area. There may be multiple terraces associated with some stream reaches, usually identifiable as distinct steps along the channel, but sometimes the lowest terrace is contiguous with the floodplain, and is identifiable only with measurements based on the bankfull stage.

Riparian Ecosystem: The riparian ecosystem is usually defined simply as the area that lies along a stream channel, and this is generally the usage we adopt in this report. Specicifically we define riparian ecosystems as a linear corridor of variable width along perennial, intermittent, and ephemeral streams exhibiting distinctive geomorphic features and vegetation communities in response to the periodic exchange of surface and ground water between the stream channel and adjacent areas.

Flood Channel: In a developed environment, protection of life and property requires that containment of floodwaters be a part of the design criteria for stream systems. The design templates presented here generally specify the dimensions of channel, floodplain, and terrace features appropriate to sustain a riparian community characteristic of a particular geomorphic zone, based on reference data from streams in the basin and region. The actual configuration of a restored riparian area will depend in part on the work of hydrologists calculating the overall "flood channel" size (channel, floodplain, and terraces) needed to contain a major flood.

4.2 Geomorphic Zones

We defined five geomorphic zones based on our field investigations, topographic maps, the maps and descriptions provided in the county soil survey (Wachtell 1978), and geologic maps and reports on Orange County and the region (Morton et al. 1976, Morton and Miller 1981). Figure 5 presents a generalized representation of the landscape position of each geomorphic

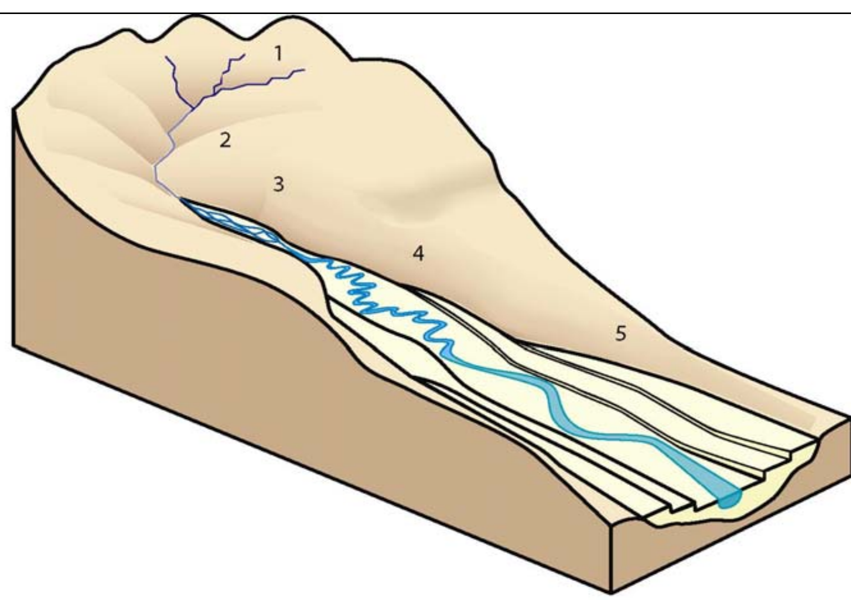

Figure 5. Generalized representation of landscape settings associated with geomorphic zone assignments

zone. We assigned each riparian reach to a geomorphic zone using aerial photography, baseline assessment data, and field evaluations. The following sections describe the typical condition of each of the five geomorphic zones in terms of geomorphology and vegetation structure. The accompanying illustrations are generalized depictions of typical examples of each zone, with vegetation communities represented by the most common dominant species and growth forms. Detailed descriptions of plant communities represented by these symbols and their variation with elevation, aspect, soils and other factors can be found in the overview of physical and biological conditions in the study area (PCR 2001) and various other publications cited in that report.

4.2.1 Geomorphic Zone 1: Riparian areas in V-shaped valleys with predominantly bedrock control

Stream channels in Geomorphic Zone 1 (Figure 6) are primarily high-gradient systems within the mountains, and first-order streams in the foothills. Geologic mapping (Morton and Miller 1981) usually indicates no Quaternary alluvial deposits, although small terrace fragments may be present. Generally, streambanks are carved directly into adjacent hillslopes, and riparian vegetation is restricted to the channel edges and banks. Hillslope vegetation, usually chaparral, coastal sage scrub or oak woodland, extends to the top of the bank. Many streams in this zone are in relatively good condition, because the adverse impacts of past land uses (primarily grazing) have been moderated by the influence of bedrock control on channel incision, and because a large percentage of these streams are within the National Forest.

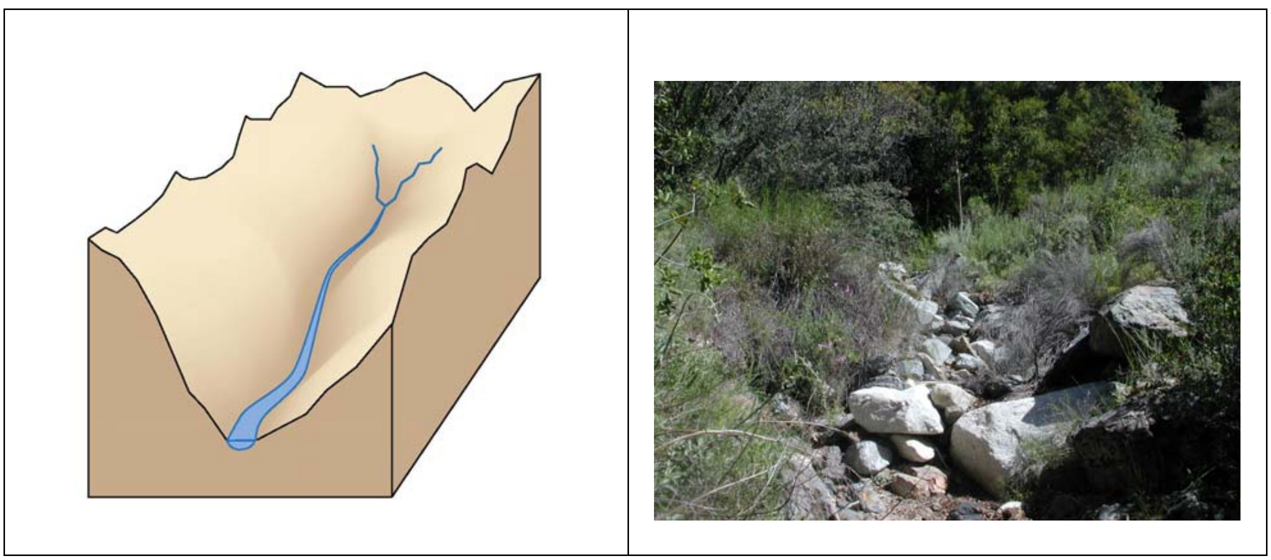

Figure 6. General form of Geomorphic Zone 1 and view of typical reach.

4.2.2 Geomorphic Zone 2: Small floodplains and terrace fragments in mountain and foothill valleys, where meander belt formation is restricted by lateral impingement of alluvial fans, colluvium, and large boulder bars.

Stream channels in Geomorphic Zone 2 (Figure 7) have a sinuous, meandering appearance on topographic maps and aerial photos, but in fact are winding between alternating fan, colluvium, or boulder bar deposits. Streams in this zone are confined by colluvium, boulder bar deposits, or bedrock, and have narrow floodplains, and narrow, discontinuous terraces. Riparian vegetation is restricted to the floodplains and terraces, with sycamore, willows, and mulefat forming narrow strips along the channel through fan and colluvial sections that are flanked by oak woodlands that extend upslope on the colluvium or fan. On many streams, particularly within the mountains and deep canyons, large boulder bars occur at intervals along the channel, and often appear to be the result of landslides immediately upslope. These bars may develop thin soils, and have the appearance of terraces more typical of meandering-stream segments (e.g., Zone 4, below). However, the boulder-bar terraces are relatively unsorted material, with uneven, hummocky surfaces. The boulder-bars are typically well-drained, and support various riparian species including alders, big-leaf maple, oaks, sycamores, or other species, depending on elevation, position in the watershed, age and activity of the deposit, and other relevant factors. Because the boulder bars, colluvial deposits, and fans that characterize Zone 2 occur as relatively large and variable units (rather than narrow streamside strips), and because extensive oak woodlands are generally part of the lower-slope

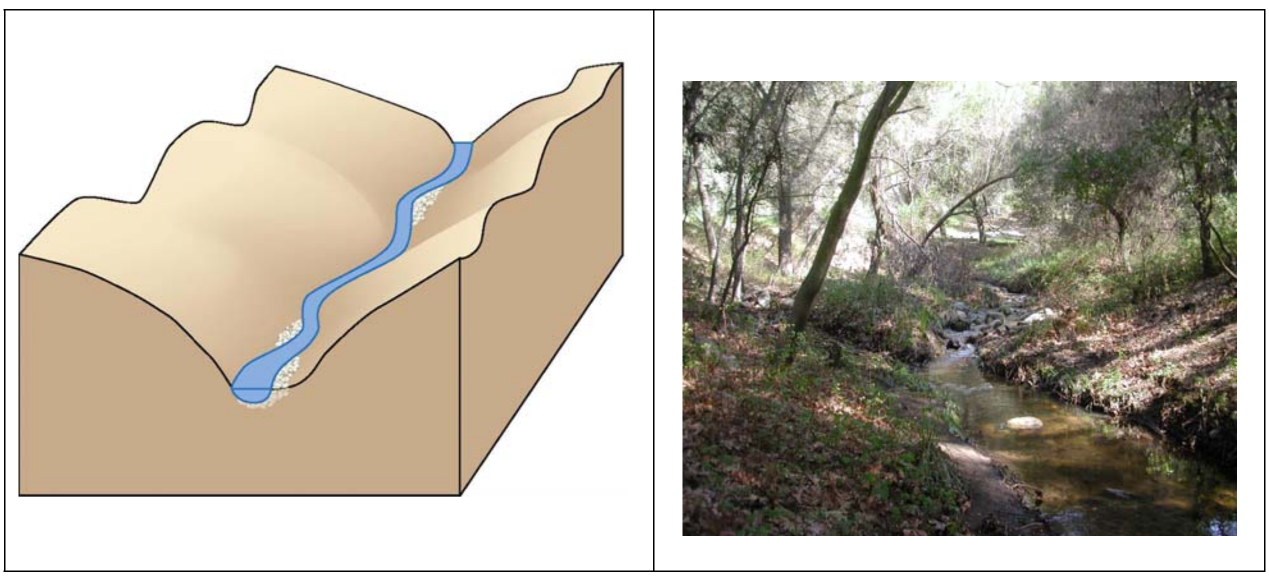

Figure 7. General form of Geomorphic Zone 2 and view of typical reach.

community, these tend to be among the most structurally and compositionally diverse riparian systems within the study area. In the foothills, Zone 2 channels are less diverse. Boulder bars are less prominent features than colluvial material, and oak woodland communities may be fairly restricted in distribution.

4.2.3 Geomorphic Zone 3: Boulder-dominated floodplain and terrace complexes.

Geomorphic Zone 3 (Figure 8) is characterized by deep, extensive accumulations of boulders and cobble that extend from valley wall to valley wall (as opposed to the discontinuous boulder bars that occur in Geomorphic Zone 2) that may or may not be mapped as Quaternary Alluvium (Morton and Miller 1981) depending on their size. This type occurs in two basic settings. Within relatively confined valleys, where Zone 2 settings predominate, the valley bottoms sometimes widen abruptly, then return to a more confined configuration. Zone 3 reaches occur within the wider zones, and local landslides are the likely source of the coarse valley fill material (Morton et al. 1976). Often, the wider valley bottoms and Zone 3 reaches occur where large tributaries enter the stream and abruptly alter the flow and sediment regime of the receiving channel. Similarly, Zone 3 reaches sometimes are found where streams exit from mountain valleys, abruptly losing their confinement and creating extensive boulder deposits before transitioning to Zone 4.

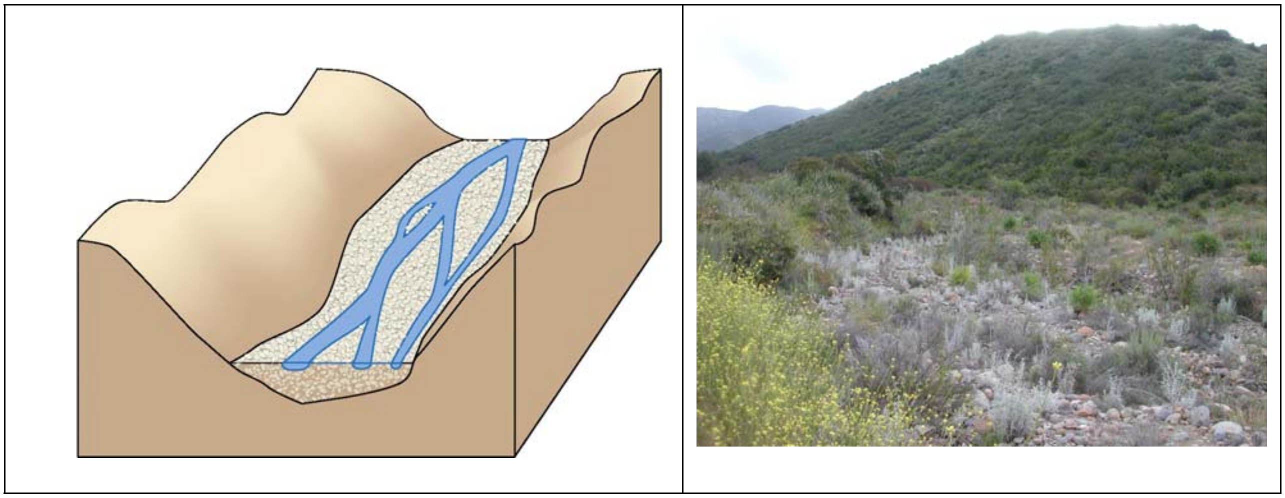

Figure 8. General form of Geomorphic Zone 3 and view of typical reach.

Typically, the Zone 3 valley bottom consists of boulders and cobbles arranged in large bars, some of which are uniform enough to be considered recognizable terraces. However, the surfaces of these bars and terraces are uneven and hummocky, often having distinct piles of rock against large boulders or logs, or along channels. Most Zone 3 reaches have a single principal channel, but it is common for the main channel to split or braid into a multiple high-flow channels that course across the terraces. Overstory vegetation, when present, consists of a sparse distribution of sycamore. Shrub and ground-layer vegetation is highly variable – mulefat and other typical riparian species are most common in the mountains, but at lower elevations a more xeric community sometimes occurs that is dominated by coastal sage scrub species.

In some instances, Zone 3 settings include fragments of fine-grained, level terraces along the valley walls. These areas usually are dominated by oaks, and they suggest that some of the areas classified here as Zone 3 were, at one time, similar to Zone 4 riparian areas (described below). In these instances, it is likely that historic events (fire, mining, changes in land use) caused runoff events sufficient to strip the fine sediments from the terraces, leaving behind relatively unsorted boulder, cobble and gravel deposits. Regardless of the origin of these sites, no restoration action can usefully modify the boulder/cobble substrates. For the purposes of this report, the boulder/cobble substrate is regarded as the "natural" template for all sites classified as Zone 3, and the open-canopy, sycamore-dominated community, usually flanked by oaks on lower sideslopes and fine-grained terrace fragments, is the restoration target.

4.2.4 Geomorphic Zone 4: Alluvium of meandering channels within broad lowland valleys.

Sites in Geomorphic Zone 4 (Figure 9) are mapped as Quaternary Alluvium (Morton and Miller 1981), and occur primarily within the foothills. Under natural conditions, these sinuous channel systems meander widely across the valley floor, have well-developed floodplains with alternating bars, and one or more broad terraces dominate the remainder of the valley bottom. The dynamic nature of this system promotes maintenance of a compositionally and structurally diverse plant community. Channel migration continually removes and creates substrates, ensuring patchy distribution of pioneer communities (such as mulefat and willows) in multiple age classes. Low terrace communities include long-lived canopy trees such as sycamores and ash, as well as tall shrubs such as elderberry and mulefat. High terraces, and colluvial slopes or fans that overlie the edges of the alluvial terraces, support oak woodlands, transitional riparian species (e.g. *Rhus*) or coastal sage scrub. Where soils are extremely sandy, or where cobbles predominate, terraces within Zone 4 support a sparse sycamore canopy layer, but the ground

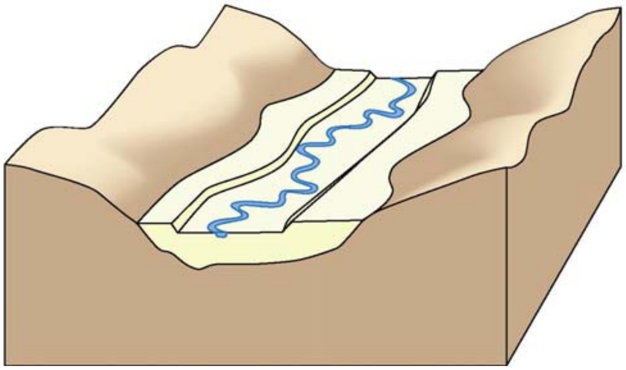

Figure 9. General form of Geomorphic Zone 4 and view of typical reach.

cover and shrub layers are dominated by a mix of xeric, scrub species (e.g. *Opuntia*). Overall, the effect is a broad and complex riparian system with upland elements fingering into the valley bottom, further increasing community diversity.

Most examples of this type within the study area have been extensively altered. Nearly all reaches exhibit historic downcutting of channels, and terraces often are dominated by non-native plant species. In these cases, the principal recommended restoration action is re-establishment of appropriate vegetation on the terraces that have been converted to other uses, and possibly creating new low terraces by partial excavation of the existing terrace system. In many other instances, historic impacts have fundamentally altered the geomorphic setting. Extensive lateral erosion has removed much of the terrace system, creating a broad channel and active floodplain zone, and a cobble-dominated valley floor where fine-grained terraces previously existed. In these cases, restoration options are somewhat limited by the loss of alluvial soils, and a fairly simple riparian community that more closely resembles the Zone 3 sycamore/mulefat type is the best that can be achieved. In these cases, it becomes particularly important to focus on restoration of valley-margin vegetation (e.g. oaks) if a diverse community composition and structure is to be re-established.

4.2.5 Geomorphic Zone 5: Large alluvial valleys.

Geomorphic Zone 5 (Figure 10) is applied only to the lower portions of San Juan, Trabuco, and Oso Creeks. Historically, the large valley bottoms comprising Zone 5 have been formed and maintained by highly active streams that in some situations have carried large amounts of sediment leading to aggrading conditions and in other situations removed sediment leading to deep channel incision. The result has been the creation of broad floodplains and extensive terrace systems. Several terrace levels are present, but there are at least two major levels – an upper terrace dominated by oaks, and a lower, sycamore-dominated terrace. The floodplain also includes sycamore, as well as extensive and dynamic mulefat and willow communities.

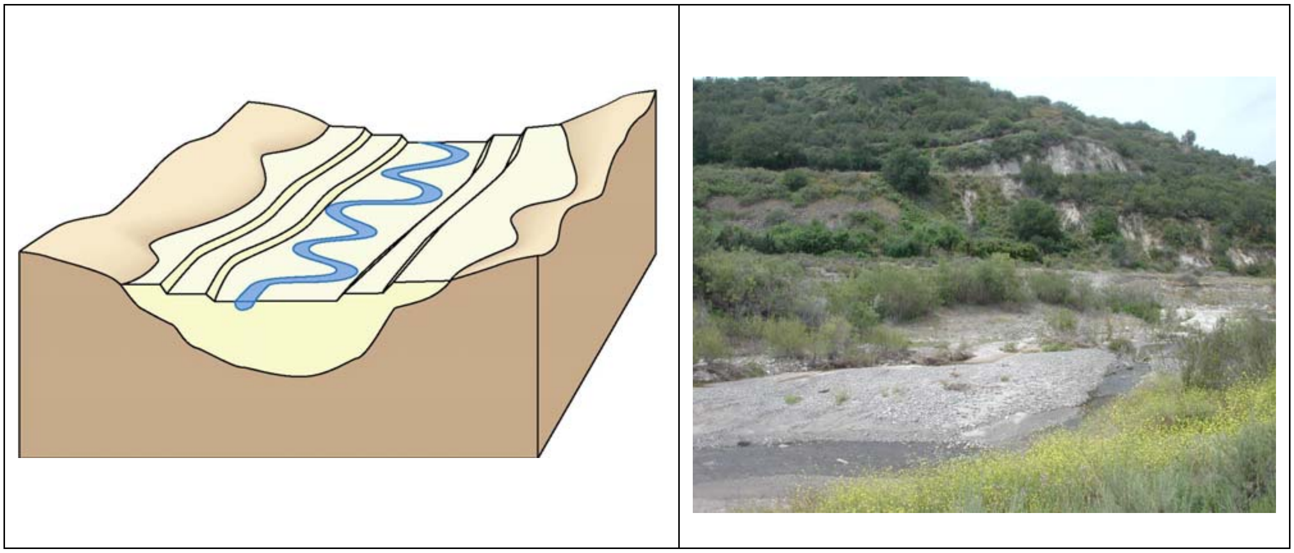

Figure 10. General form of Geomorphic Zone 5 and view of typical reach.

The flooding and mining damage documented in the past century have evidently removed much of the historic terrace system, especially in the lower San Juan Creek. Within the active floodplain, many areas have been heavily infested by exotic species, especially *Arundo donax.* Fundamental land use changes, as well as presumed resulting changes in flooding patterns and water availability within the now-perched terraces, requires a modified restoration approach. The pre-settlement condition is not a reasonable target for restoration; rather a modified restoration target is needed that recognizes the limitations of the damaged landscape and seeks to establish communities appropriate to the altered site conditions.

4.3 Restoration Templates

We developed a classification of potential Restoration Templates for riparian ecosystems in various states of cultural alteration, applicable across all Geomorphic Zones. We analyzed each riparian reach to establish specific restoration criteria in terms of channel cross section and form, the scale of terraces present, and dominant vegetation types appropriate to each of the Restoration Templates. Using aerial photography, baseline assessment data, our knowledge of each riparian reach acquired during baseline assessment field sampling, and field verification, we assigned one of six restoration templates to each riparian reach based the condition of the channel, riparian vegetation, and surrounding land uses. The assigned restoration template was intended to represent the best possible restoration target, given the potential natural patterns expected for the Geomorphic Zone, as described above. The objective of each template is to re-establish, to the extent possible, all of the vegetation zones present under relatively natural conditions, and in relative proportions approximately corresponding to the extent of the geomorphic surfaces found in relatively intact reference reaches. In some cases we divided riparian reaches, and assigned a different Restoration Template to each riparian reach. For example, where the upstream or downstream end of a riparian reach consisted of a short segment of engineered channel (i.e., culvert under a road) a different Restoration Template was assigned.

All templates were assigned based on the potential to establish natural plant communities with composition, structure, and overall diversity characteristic of the geomorphic zone. Analyses of habitat requirements for animal species of concern in the region indicate that complex and diverse riparian plant communities are among the key determinants of habitat quality (e.g Franzreb 1989, Finch et al. 2000). In order to re-establish such conditions, floodplains, terraces, and adjacent uplands must be available for restoration, and those surfaces must be restored to appropriate relative elevations (height relative to bankfull stage) to establish self-sustaining plant communities.

All templates include a zone of native upland vegetation as part of the overall riparian corridor, in addition to the riparian vegetation associated with the channel and terrace systems. For the purposes of assigning a restoration template, it was necessary to estimate whether sufficient upland area was available to form an adequate buffer. What constitutes an "adequate" upland buffer is a complex question that is beyond the scope of this project. For our purposes, a minimum of 30 m of space adequate to support native upland vegetation is required on each side of the riparian vegetation corridor. This is consistent with generalizations that have been published regarding minimum buffers for a wide variety of avian species (Fischer and Fishenich 2000). As noted, this is a minimum figure – final restoration designs should incorporate recommendations from resource agencies, because specific regional and local conservation priorities may dictate wider buffers.

Finally, it is important to recognize that the restoration templates presented below are intended to be just that - general templates structured specifically to determine the feasibility of restoring individual reaches, and to prioritize restoration actions based on the functional benefits likely to be realized. Although we expect that final restoration designs will resemble these templates and associated relative dimensions, site-specific restoration designs will have to be developed that include grading plans and specify planting stock, planting densities, irrigation practices, and similar requirements.

Many stream reaches in the study area, though degraded in various respects, still support dense native riparian vegetation in the immediate vicinity of the channel. In order to avoid adverse impacts to mature, native riparian vegetation present at a restoration site, the restoration templates may need to be adapted. As appropriate, modifications to the restoration templates may include limiting the planting activities to terraces and adjacent lower hillslopes without excavation of alluvial material.

The six restoration templates are described below. Note that these are general descriptions applicable across all Geomorphic Zones.

4.3.1 Natural Template

The Natural Template (Figure 11) is assigned where channel, floodplain, and terrace morphology and vegetation, as well as an upland buffer of native vegetation, can be restored to a condition approximating the estimated undisturbed condition for the Zone and site-specific conditions. Some stream incision is acceptable in this category, providing it has not caused a complete and irreversible shift in vegetation distribution. Generally, the designation of the Natural Template applies to reaches with sufficient room for a floodplain and terraces with hydrologic conditions required to sustain characteristic vegetation. For example, many channels in Zone 4 have a high terrace that supports mature sycamores, but there is no evidence of sycamore reproduction, and coastal sage scrub species are establishing on the terrace. In such cases, due to channel incision, the conditions necessary to establish sycamore no longer prevail, and the Natural Template would not apply. Most reaches in Geomorphic Zone 1, and a large

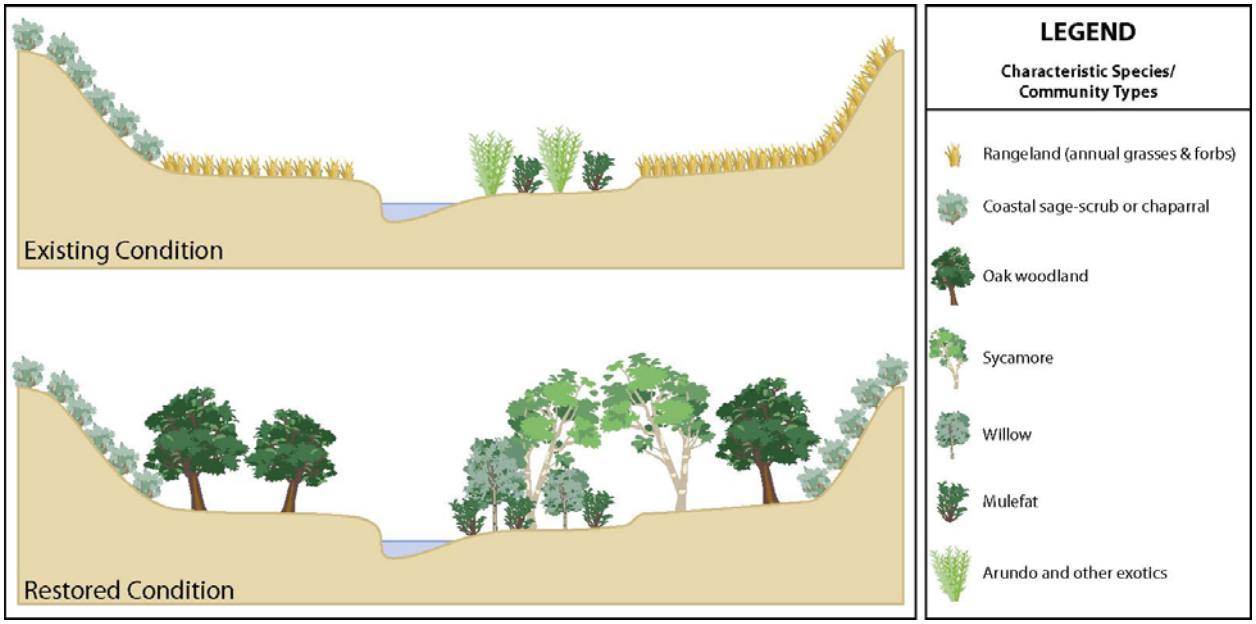

Figure 11. Typical pre- and post-restoration conditions of riparian reaches assigned to the Natural Template

percentage of Zone 2 reaches were assigned to the Natural Template, indicating that they can be fully restored, or are already fully functional. In such cases, restoration is largely a matter of localized re-establishment of native vegetation, and control of exotic species, as illustrated for a typical Zone 2 reach in Figure 11. Some excavation and re-configuration of alluvial material may be appropriate in cases where a stream is moderately incised, channelized, buried, or re-routed, but can be fully restored.

4.3.2 Incised Channel Template

The Incised Template (Figure 12) was applied to channels that had been incised or laterally scoured such that the existing condition did not fall into the normal range for channel, floodplain, or terrace dimensions, but where the full variety of community types expected for the Geomorphic Zone could be re-established in proportions generally reflecting the undisturbed condition. In many cases, some reconfiguration of existing alluvium is feasible, allowing re-establishment of appropriate channel and floodplain dimensions to help arrest excessive erosion. In certain instances, some sculpting of terraces is possible. In situations where the Incised Template is assigned but no opportunity exists for significant earthmoving, it indicates that all surfaces (terraces, floodplain, etc.) are present to a sufficient extent that all native plant communities can be re-established, though perhaps not to their full pre-disturbance extent. Most

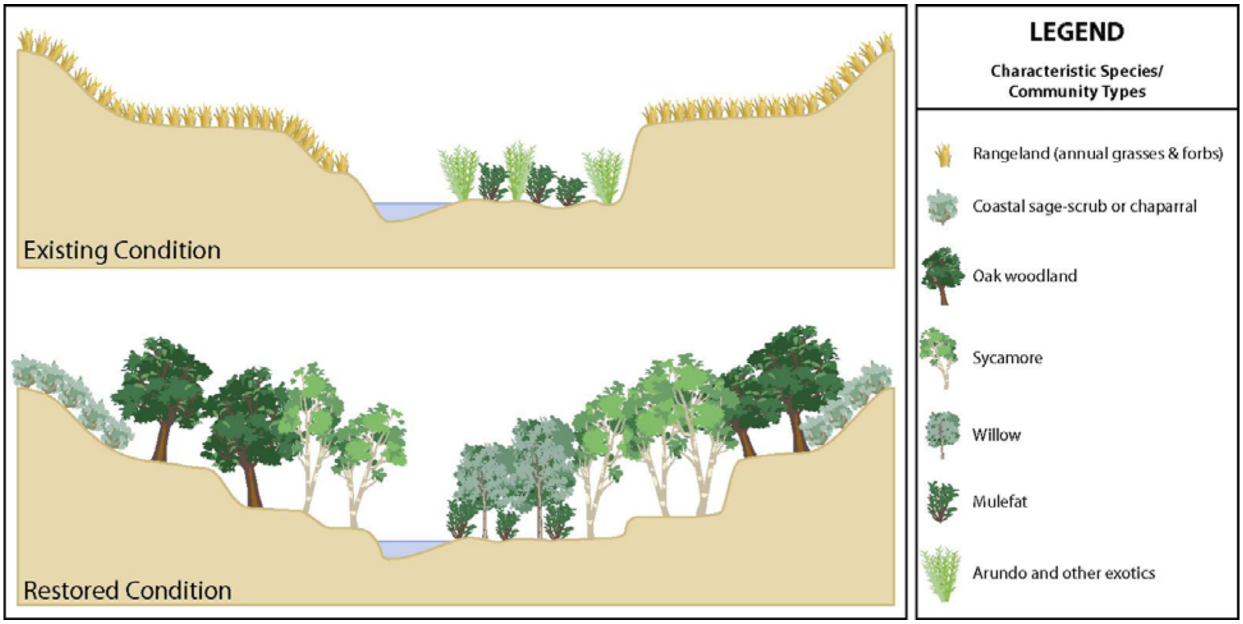

Figure 12. Typical pre- and post-restoration conditions of riparian reaches assigned to the Incised Template

reaches assigned to the Incised Template are in Geomorphic Zones 2, 4, or 5. Figure 12 illustrates a typical Zone 4 incised condition, and the proposed restoration approach, which includes reconfiguration of surfaces, removal of exotic vegetation, and extensive native plantings.

4.3.3 Constrained Channel Template

The Constrained Template (Figure 13) was assigned to channels that would otherwise be included within the Incised Template, except that the immediately adjacent landscape prevents the restoration of one or more components of stream corridor geometry (e.g., floodprone width, sinuosity, terrace configuration) to normal ranges. This template was typically applied where surrounding infrastructure (roads, buildings) irreversibly crowds the incised channel. In these cases, field evaluation indicated that sufficient room would be present to establish functional, and presumably stable (equilibrium) channels and floodplains, but that room to establish terraces and upland buffers would be is inadequate to approximate conditions found in reference systems. Thus, stream segments restored based on the Constrained Template have all vegetation communities present, but one or more of those communities is substantially reduced in extent from the normal reference condition. A constrained system, i.e., one without room to adjust to extreme events, is expected to be less functional in various ways than more complete systems,

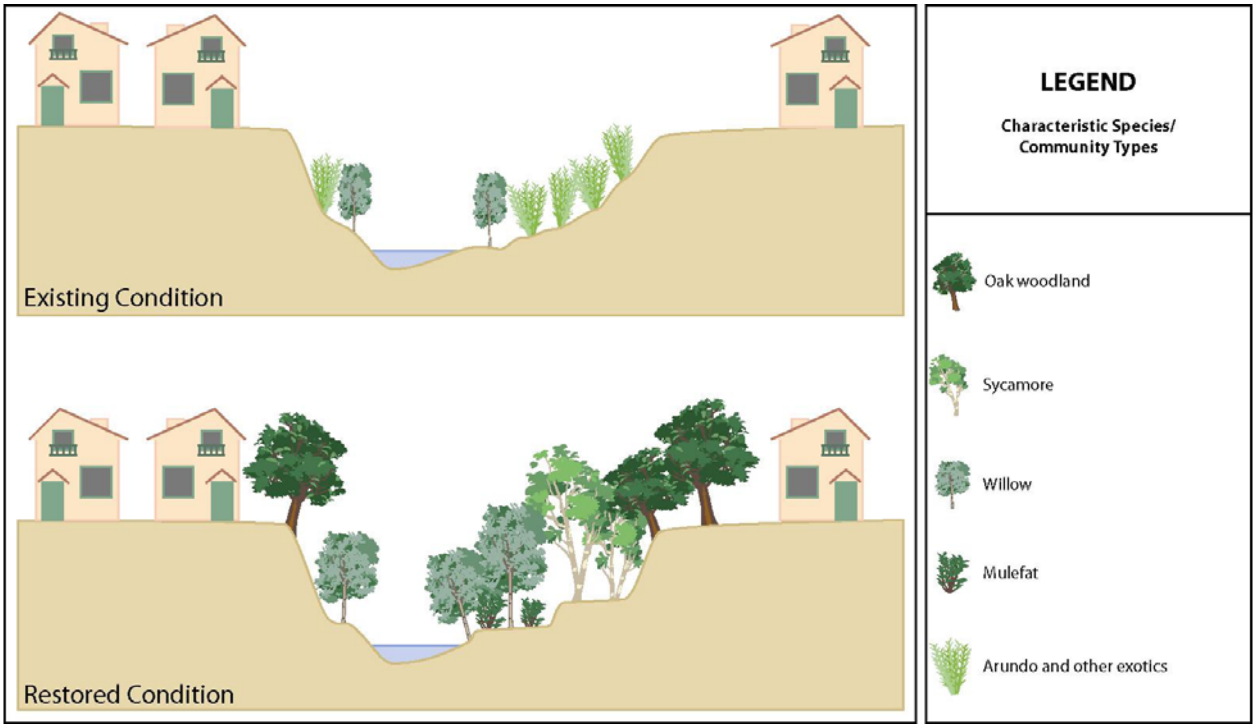

Figure 13. Typical pre- and post-restoration conditions of riparian reaches assigned to the Constrained Template

making successful restoration efforts more uncertain, as compared with less constrained systems. The Constrained Template was assigned to stream reaches in all Geomorphic Zones except Zone 1. Figure 13 illustrates a typical application, where minor substrate reconfiguration is used to create surfaces sufficient for establishing narrow zones of different communities across a range of elevations relative to the stream channel.

4.3.4 Aggraded Channel Template

Many stream reaches exhibit some degree of aggradation, but in most cases the stream has adjusted to the historic deposition, incising through the valley fill and leaving extensive amounts of sediment stored in terraces. The Aggraded Template (Figure 14) is applied only to those reaches where the channel and floodplain are currently filled with sediments such that there is no distinct organization of surfaces. The channel moves through a broad flat that spans from valley wall to valley wall (or terrace to terrace), and the historic floodplain is buried beneath one to several feet of fill. Aggraded reaches occur in one of several situations: where in-stream structures were placed to pond water, and the storage basins have since filled with sediments; where such structures have failed or been mechanically breached, and the downstream reaches

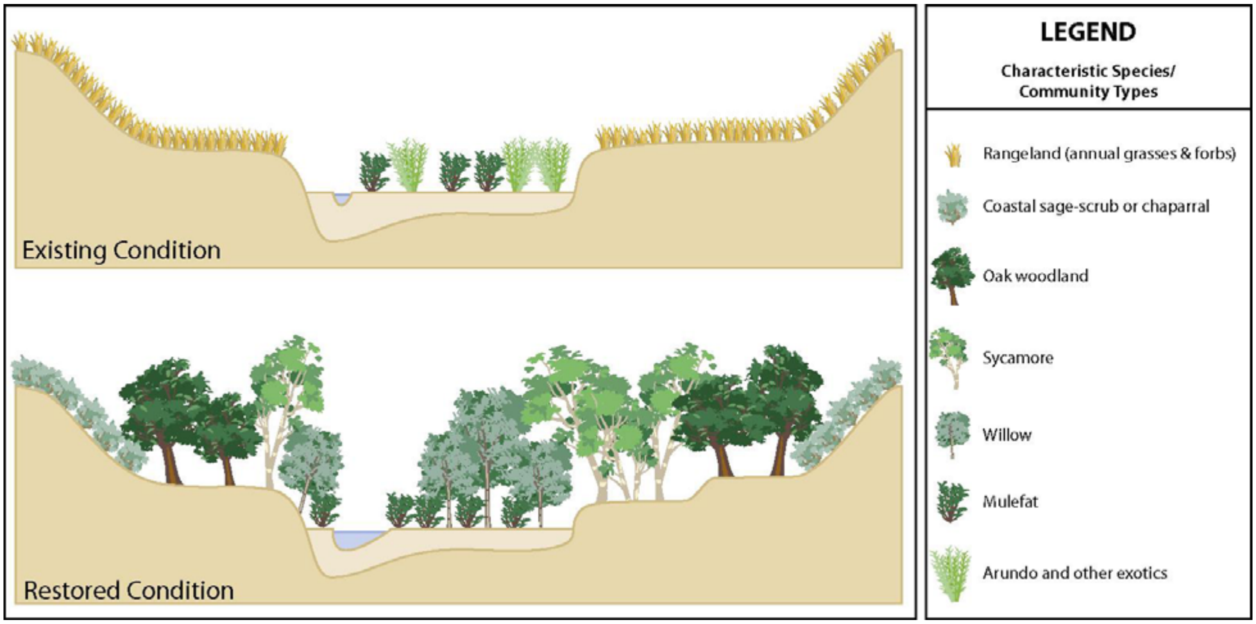

Figure 14. Typical pre- and post-restoration conditions of riparian reaches assigned to the Aggraded Template

are receiving the stored sediments; or where material from major historic erosional events (due to mining, fire, tributary incision, etc.) has accumulated in the lower reaches of major streams.

Within the study area, only a few reaches meet the criteria for the Aggraded Template. In each case, only minor channel reconfiguration (or none at all) would be appropriate. However, most aggraded sites require fairly extensive establishment of native plant communities on one or more riparian surfaces, as illustrated in Figure 14.

4.3.5 Engineered Channel Template

Stream segments that are confined within concrete or riprap "banks" and which must remain so due to flood conveyance and safety concerns, or because only very limited recovery of ecological benefits is feasible, are assigned to the Engineered Template (Figure 15). Through minimal restoration of native vegetation, this template may provide some, albeit limited, increase ecosystem function such as slowing the spread of exotic plant species, and establishing a movement corridor (primarily for avian species) between more functional riparian areas up- and down-stream. Although some concrete-walled channels have natural channel materials in the bottom (rather than concrete) and are designed to accommodate some native vegetation within the channel, others may be adaptable to a change in management, or even be modified to replace one of the engineered banks with a natural bank and native vegetation. Certain concrete

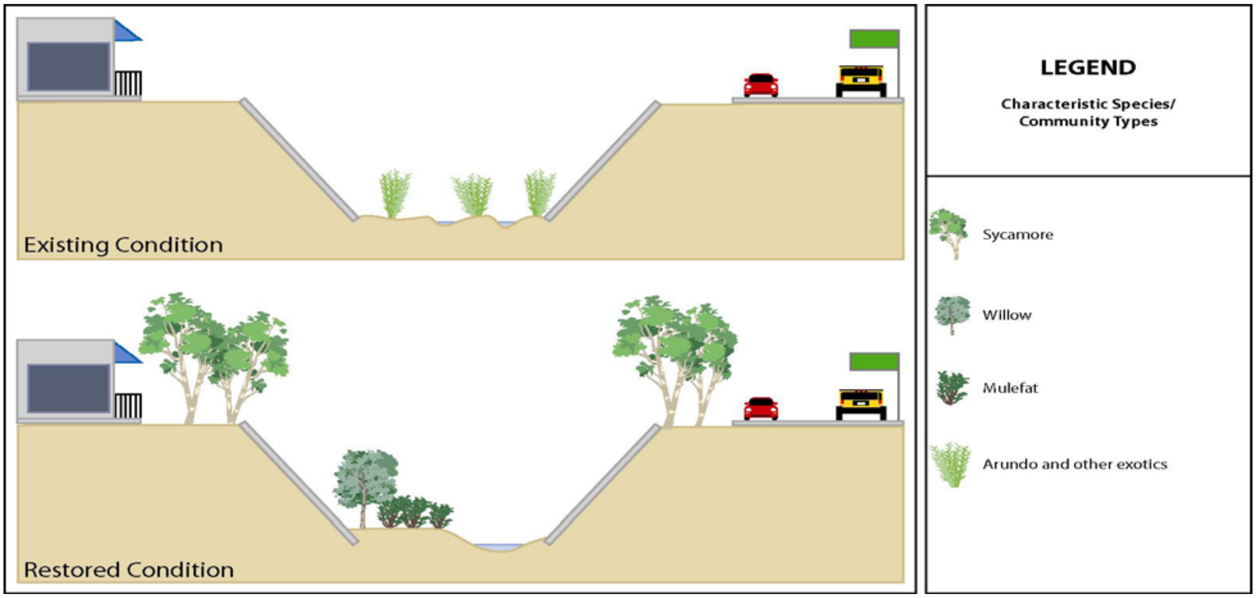

Figure 15. Typical pre- and post-restoration conditions of riparian reaches assigned to the Engineered Template

channels may not be candidates for any change in design or management, and can only be retrofitted with a narrow strip of vegetation on the upland edge of the concrete wall. In any of these cases, the potential for significant restoration of a suite of functions is very limited, and the Engineered Template is intended only to address some specific deficiencies and thereby improve functionality of more complete riparian areas elsewhere in the basin. The Engineered Template is applicable primarily to Geomorphic Zones 4 and 5.

4.3.6 Restoration Impractical

This template is applied to stream segments where there is no practical way to address the deficiencies present, within the general guidelines adopted for this study that preclude recommending fundamental changes to major roads and developed areas, or massive excavations. Thus, stream segments that pass under highway corridors within culverts, and lengthy stream segments that have been converted to the underground storm drain system through residential areas are assigned the Restoration Impractical designation (template), which means that no action is recommended. Should planners determine that restoration of a stream segment in this category is feasible, then the segment can be assigned to the appropriate template and the action re-assessed. Note that not all underground or engineered stream segments are rated "impractical" to restore, particularly if they pass through agricultural areas or greenways, where daylighting or channel reconfiguration would not disrupt existing infrastructure.

4.4 Level of Effort

Based on the field evaluation of all riparian reaches we also developed a scale estimating the level of effort that would be required to restore a riparian reach to the prescribed Restoration Template. Using aerial photography, baseline assessment data, and field verification, we assigned a level-of-effort category to each riparian reach. The level-of-effort measure was intended to serve as a tool for planners based on the assumption that there would be limited resources available for restoration, or limited potential sites would be available to offset certain types of impacts, and it may be useful to consider cost as a factor in the event that a variety of potential scenarios must be assessed for feasibility and efficacy. To that end, the level-of-effort scale represents a crude, ordinal scale, estimate of restoration costs. This simply means it will cost more to restore areas assigned greater level-of-effort units, but exactly how much more can only be determined on a case by case basis. In addition, there is no consideration of land purchase costs or similar issues included in these estimates, and unforeseen issues could easily change the estimates dramatically.

4.4.1 Level of Effort - None

Since the reach is functional in its current condition, and requires only vigilance to prevent invasion of exotic plant species, no restoration is considered necessary. In the figures below, these reaches are assigned one Level of Effort unit (rather than a zero) to facilitate the calculations used in the assessment process as well as to reflect that surveillance and management activities are anticipated.

4.4.2 Level of Effort - Light Planting

No reconfiguration of the land surface is needed. Treatment consists of control of exotic species and spot-planting of native plants. Typically, this would involve hand-planting of willows at the base of an unstable bank, or adding species that may have been grazed from a community back into an otherwise intact riparian area or upland buffer. Three Level of Effort units are assigned to reaches in this category.

4.4.3 Level of Effort - Light Earthwork / Heavy Planting

This treatment is prescribed where, in addition to the activities mentioned under "Light Planting," a large numbers of plants must be introduced and/or substantial mechanical site preparation is needed (i.e., "Heavy Planting"). Under this designation, site contours are not reconfigured, but grubbing, tilling and similar site preparation may be required prior to planting. Generally, activities in this category are limited to those that can be accomplished with a farm tractor or similar types of equipment. Five level-of-effort units are assigned to reaches in this category.

4.4.4 Level of Effort - Moderate Earthwork / Heavy Planting

This level of effort is assigned to stream segments and associated riparian areas that require reconfiguration in some areas, although other portions may be restored with the simpler methods described above. Moderate Earthwork is intended to indicate widening of floodplains and terraces in systems where channels are not deeply incised, but need more space to re-establish equilibrium and community diversity. Typically, this will involve excavation of less than 6 feet of soil depth, though there is no implication regarding the lateral extent of the excavation. Generally, this work could be accomplished with a backhoe or similar type of equipment. The Light Earthwork level of effort designation includes the assumption that Heavy Planting will be required, including the site preparation activities described in that section, above. Seven level-of-effort units are assigned to reaches in this category.

4.4.5 Level of Effort - Heavy Earthwork / Heavy Planting

This level-of-effort designation applies to a wide range of possible actions, all of which will end with the Heavy Planting site preparation and planting requirements described above. Sites designated as needing Heavy Earthwork may be deeply incised channel segments that require extensive soil removal to re-establish floodplains and terrace systems tens of feet below the current grade, and grading back of high vertical banks to stable angles of repose. The sites may also require cutting of new channel systems with adequate length to allow meander behavior where the original channels have been filled and replaced with engineered channels. Additionally, removal of concrete, rip-rap, or asphalt bank protection, and other major site reconfiguration activities are anticipated. Equipment needed is likely to include bulldozers, graders, track-hoes and similar heavy equipment. Ten level-of-effort units are assigned to reaches in this category.

4.4.6 Level of Effort - Impractical

Although we have proceeded with the restoration plan on the assumption that reaches in the "impractical" category would not be likely candidates for restoration due to the extreme effort required, we have included them in this analysis primarily to illustrate their distribution relative to the other, more feasible, restoration options. Reaches considered impractical to restore have been assigned 20 level-of-effort units. In reality, the cost of restoring “impractical” reaches could greatly exceed 20 times the cost of restoring a reach assigned a level-of-effort of 1 unit. As indicated above the actual restoration costs can only be determined on a case by case basis..

4.5 Restoration Simulations

An ArcView theme with attributes representing Geomorphic Zone, Restoration Template, and Level of Effort was developed for each riparian reach in the study area. The initial simulation was conducted to obtain post-restoration indices scores for each riparian reach in the study area. Specifically, the hydrology, water quality, and habitat integrity indices were recalculated using relevant indicator metrics/scores for each riparian reach after applying the prescribed Restoration Template to each reach. Only five of the original 19 indicators that comprise the integrity indices represent riparian reach scale factors, so only the five indicators were assigned new metrics/scores of 1 to 5, with 5 representing conditions of a fully functional riparian reach. Generally, indicators representative of local drainage area scale or drainage basin scale factors of hydrologic, water quality, or habitat integrity of riparian ecosystems are not affected by the simulation of a Restoration Template, since the templates are applied at the riparian reach scale. However, two drainage basin scale indicators—Altered Hydraulic Conveyance - Drainage Basin (AHC-DB) and Riparian Corridor Connectivity – Drainage Basin (RCC-DB)—will acquire new indicator scores based on cumulative changes in indicators, i.e., Altered Hydraulic Conveyance - Riparian Reach (AHC-RR) and Riparian Corridor Connectivity – Riparian Reach (RCC-RR for all contributing upstream riparian reaches). Results of the initial simulation on a generic stream reach provide an indication of what may be expected for a prescribed restoration template (Table 1).

Following the initial simulation, we used the new indices for hydrologic, water quality, and habitat integrity to perform three additional simulations based on specific objectives to achieve three of many potential restoration scenarios. In the first simulation, the objective was to identify the riparian reaches where application of the restoration template would result in the maximum possible increase in riparian ecosystem integrity, regardless of the level of effort required. This first simulation assumes an infinite level of resources available for restoration, and that wherever restoration will increase integrity indices, it will be accomplished.

Table 1. New scores assigned to riparian reach scale indicators based on Restoration Template

Restoration Template	**Riparian Reach Indicators**						
	AHC-RR*	**AHC-DB**	**FI**	**SR**	**NVR**	**RCC-RR**	**RCC-DB**
Natural	5	Cumulative	5	5	5	5	Cumulative
Incised	5	Cumulative	5	4	5	5	Cumulative
Constrained	No Change	Cumulative	No Change	2	5	5	Cumulative
Aggraded	5	Cumulative	5	4	5	5	Cumulative
Engineered	No Change	Cumulative	No Change	1	5	5	Cumulative
Impractical	No Change	Cumulative	No Change	No Change	No Change	No Change	Cumulative

* AHC-RR = Altered Hydraulic Conveyance – Riparian Reach Scale
AHC-DB = Altered Hydraulic Conveyance – Drainage Basin Scale
FI = Floodplain Interaction
SR = Sediment Regime Index
NRV = Native Riparian Vegetation
RCC-RR = Riparian Corridor Continuity – Riparian Reach Scale
RCC-DB = Riparian Corridor Continuity – Drainage Basin
See Smith (2001) for description and discussion of indicators

In the second simulation, the objective was to identify the riparian reaches where application of the restoration template would result in the greatest increase in riparian ecosystem integrity while considering the level of effort required. This simulation differs from the first in that it is more selective and based on the assumption that there is a finite level of resources available for restoration, and the selection of what to restore may depend on the level of resources required, as measured by the level-of-effort units.

In contrast to restoration simulations one and two, which are confined to restoration of the riparian reach, the objective of the third simulation is to identify the riparian reaches where application of the restoration template as well as moderation of land uses in the local drainage area and drainage basin of the riparian reach would result in increased riparian ecosystem integrity. In other words, in the third simulation, the effects of revegetation on broad terraces as well as conversion of upland areas from agricultural or grazing uses to natural vegetation is considered.

5.0 Results and Discussion

5.1 Riparian Reach Classification, Template, and Level of Effort Assignments

Figure 16 shows Geomorphic Zones, Figure 17 shows the Restoration Templates, and Figure 18 shows the Level of Effort category assigned to riparian reach for the study area.

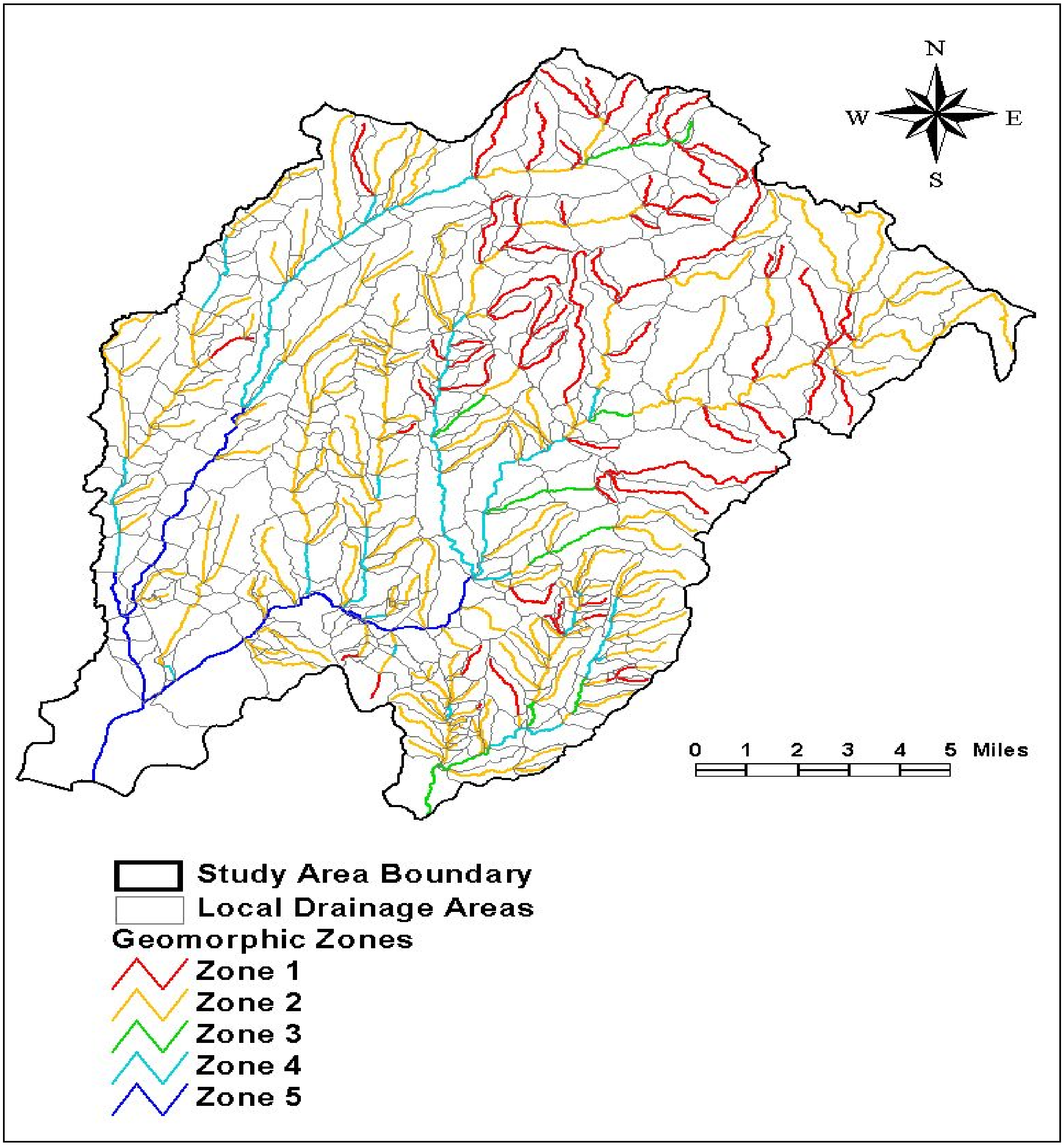

Figure 16. Geomorphic Zone assignments for riparian reaches

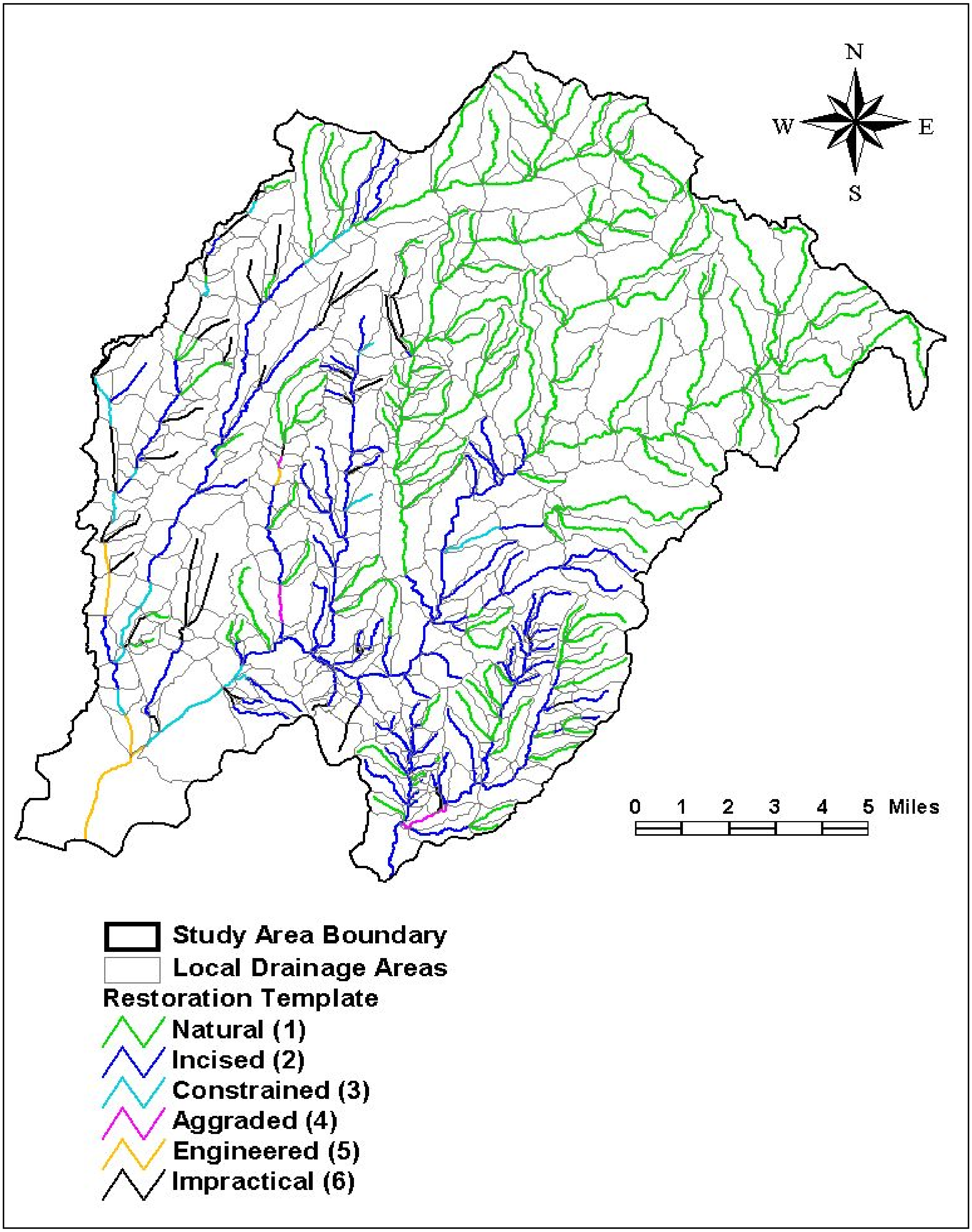

Figure 17. Restoration Template assignments for riparian reaches

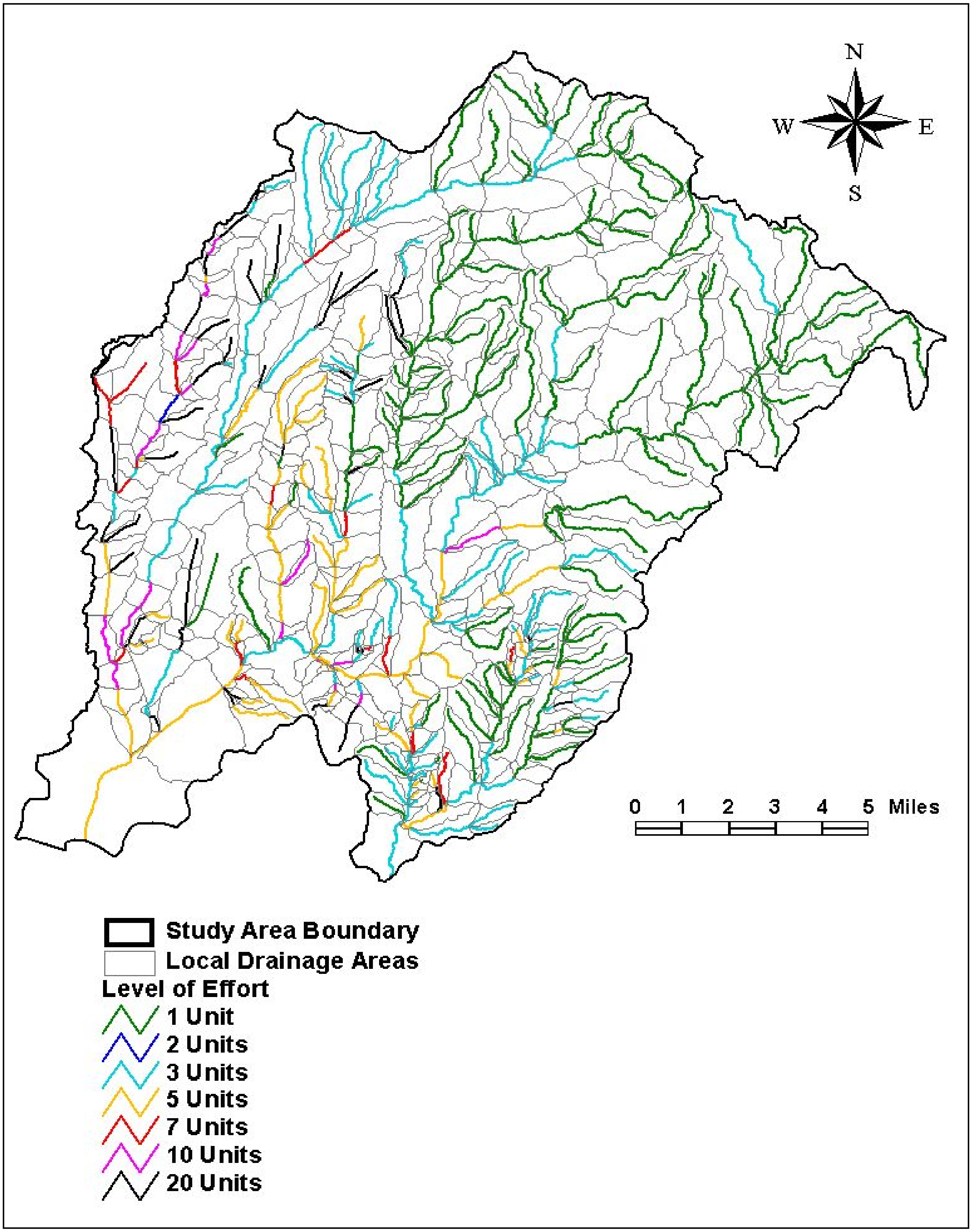

Figure 18. Level-of-Effort assignments for riparian reaches

5.2 Conceptual Restoration Design

Based on the field studies, the general Restoration Templates as illustrated and described in Section 4.3, were developed primarily for use in evaluating various restoration scenarios (see below). Additionally, the Restoration Templates also provide general restoration design guidance regarding the extent to which natural vegetation communities and riparian ecosystem function can be re-established in various modified settings. The information is intended for use as part of the overall planning-level assessment process that this document is intended to provide. Specifically, where a particular reach is proposed for inclusion in a restoration program, it may be helpful for planners to visualize the likely restored condition, and determine if it will meet specific resource objectives. Although the templates are not detailed, they illustrate the relative positions of channel, floodplain, and terrace features and their associated plant communities, viewed in cross-section.

As noted previously, site-specific restoration design is beyond the scope of this document, and specifications for features such as channel meander patterns, species composition, and the dimensions of geomorphic surfaces will have to be developed for each individual restoration site. Furthermore, in the course of conducting field studies the dimensions of geomorphic surfaces throughout the watershed, and across a range of geomorphic zones and levels of disturbance were recorded. Table 2 presents baseline ranges and average values for channel, floodplain, and terrace dimensions in each geomorphic zone, as determined from field measurements in the least-disturbed reaches remaining in the study area. These data may be used in conjunction with the previously presented restoration templates to estimate the general characteristics likely to be desirable for a proposed restoration area. In particular, for each geomorphic zone, the number of terraces normally present and their relative height and width is provided (Table 2). For example, in Zone 1, no reaches were observed with terraces. In contrast, in Zone 5, all reaches are expected to have at least three terraces with variable widths and heights. While it will be impossible to fully re-establish broad terraces in most restoration projects, the dimensions presented (Table 2) can be consulted to estimate the relative proportions of each terrace that should be present given the full range of natural community types to be re-established.

Table 2. Dimensions of geomorphic features measured in least-disturbed riparian reaches in the study area

Feature	Dimensions	Geomorphic Zone				
		1	**2**	**3**	**4**	**5**
Bankfull Width (ft)	range	1-3	1-9	2-7	4-18	10-18
	average	2.5	4.4	4.6	10.7	13.8
Bankfull Maximum Depth (in)	range	3-4	2-7	3-7	3-4	6-10
	average	3.5	3.6	5.3	3.3	8.0
Bankfull Mean Depth (in)	range	2-3	1-4	3-4	2-4	4-8
	average	2.5	4.1	3.5	2.7	5.5
Floodprone Width (ft)[1]	range	2-4	2-8	2-5	6-40	20-25
	average	3.0	3.1	3.3	18.5	22.3
Terrace 1 Width (ft)	range	NA[2]	0-40	60-150	3-125	50-100
	average	NA	9.6	105	40.8	80
Terrace 1 Height Above Bankfull (ft)	range	NA	1-4	1.5-7	1-2	1.5-3.5
	average	NA	2.2	4.6	1.4	2.6
Terrace 2 Width (ft)	range	NA	0-40	30-80	130-600	25-300
	average	NA	56.7	55	295	144
Terrace 2 Height Above Bankfull (ft)	range	NA	3-4	8-11	4-6	4-8
	average	NA	3.7	9.5	4.5	5.8
Terrace 3 Width (ft)	range	NA	NA	NA	0-350	50-200
	average	NA	NA	NA	250	125
Terrace 3 Height Above Bankfull (ft)	range	NA	NA	NA	6-9	7-20
	average	NA	NA	NA	7.5	14.4

[1] Range and average Floodprone and Terrace widths are for the individual geomorphic surfaces on both sides of the Bankfull Channel. It does not include the width of lower elevation surfaces. For example, the average width of Terrace 1 includes Terrace 1 on both sides of the channel, but does not include the Bankfull Channel or Floodplain (see Figure 4).
[2] NA = Not Applicable

5.3 Restoration Simulations

In order to provide a point of reference for the restoration simulation results, Figures 19-21 show baseline hydrologic, water quality, and habitat integrity indices for riparian reaches in the study area. The change in integrity indices in all figures below is shown at the local drainage area scale to facilitate a comparison between riparian reaches. However, it should be realized that integrity indices apply only to the riparian reach and not the full extent of the local drainage area as implied by the figures.

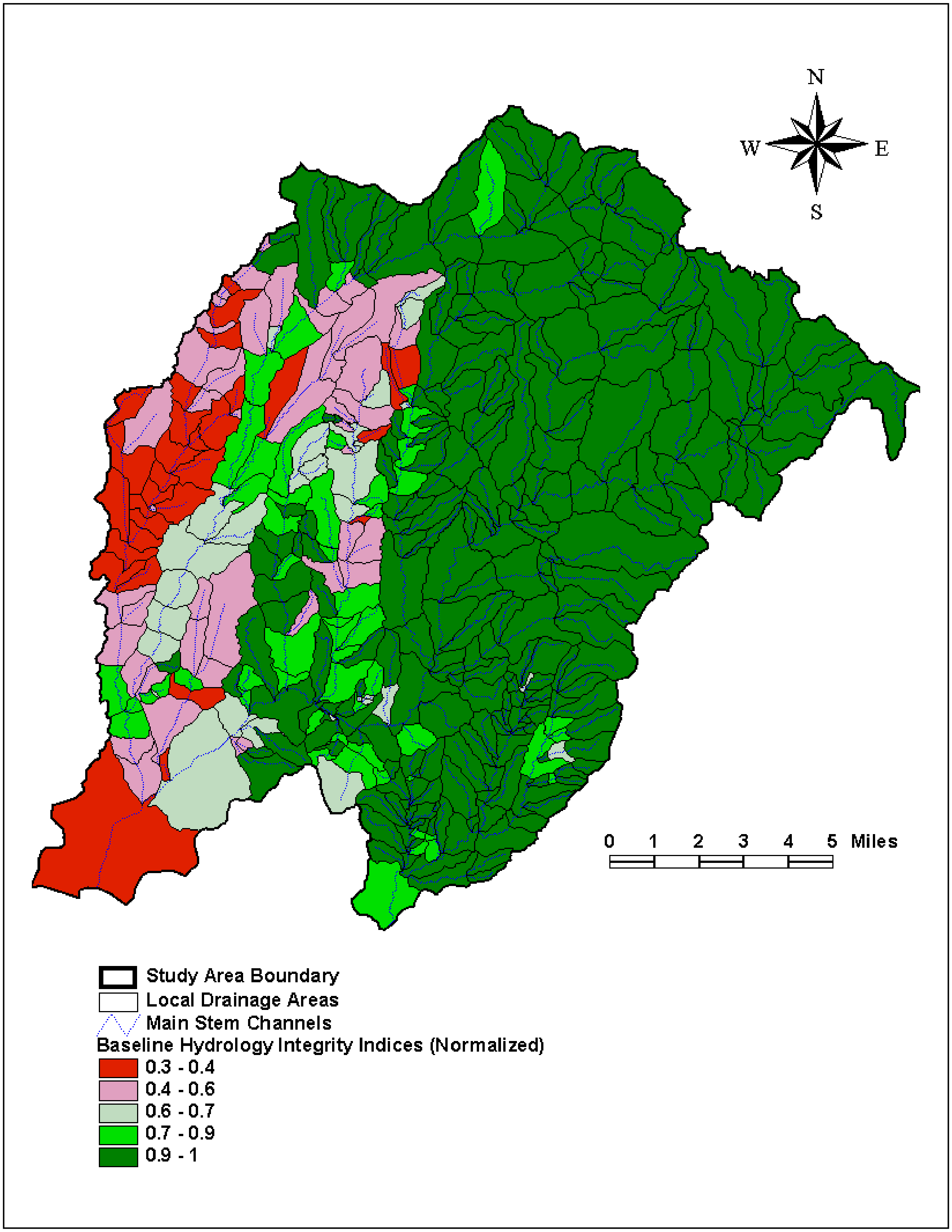

Figure 19. Normalized baseline hydrology integrity indices for riparian reaches

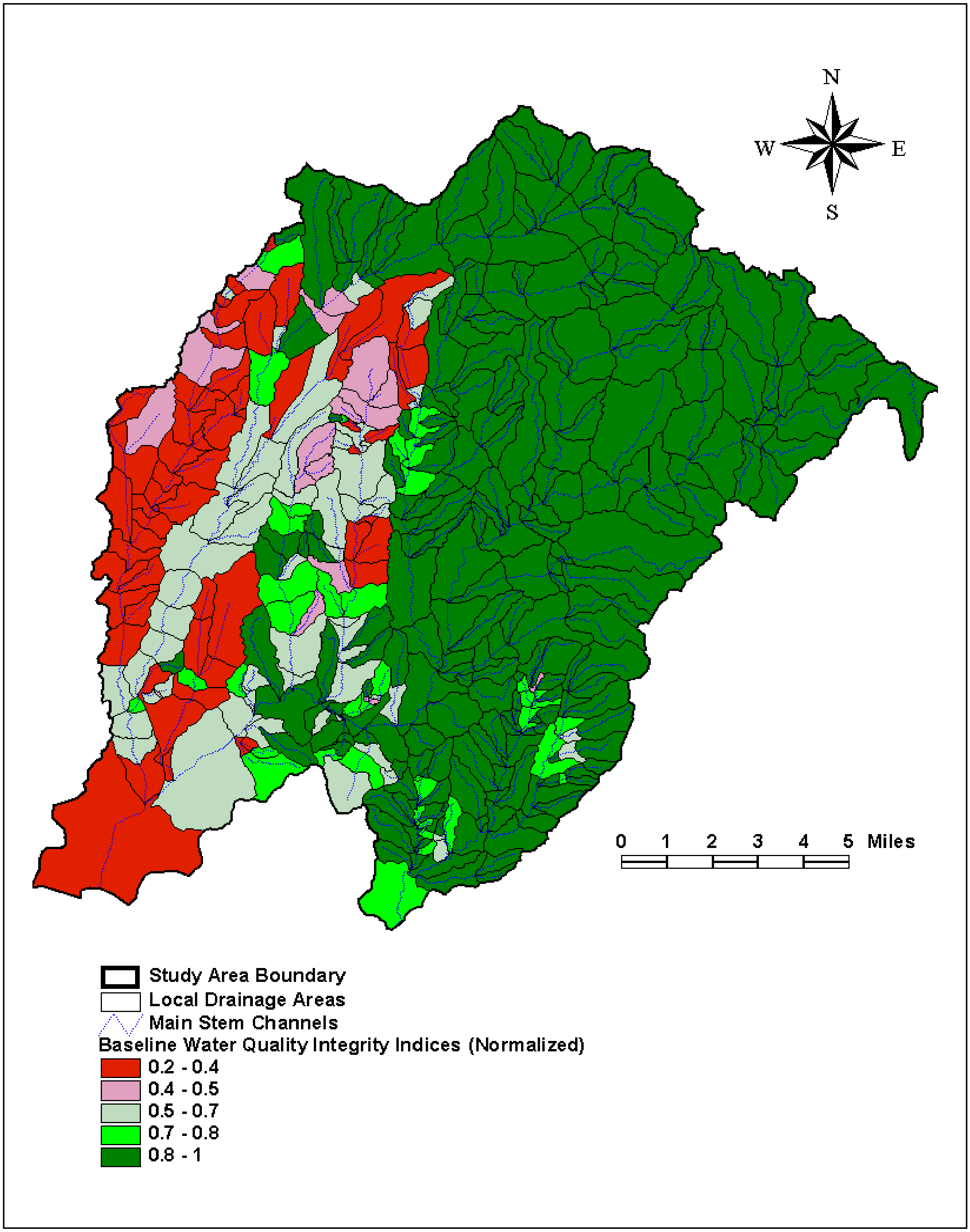

Figure 20. Normalized baseline water quality integrity indices for riparian reaches

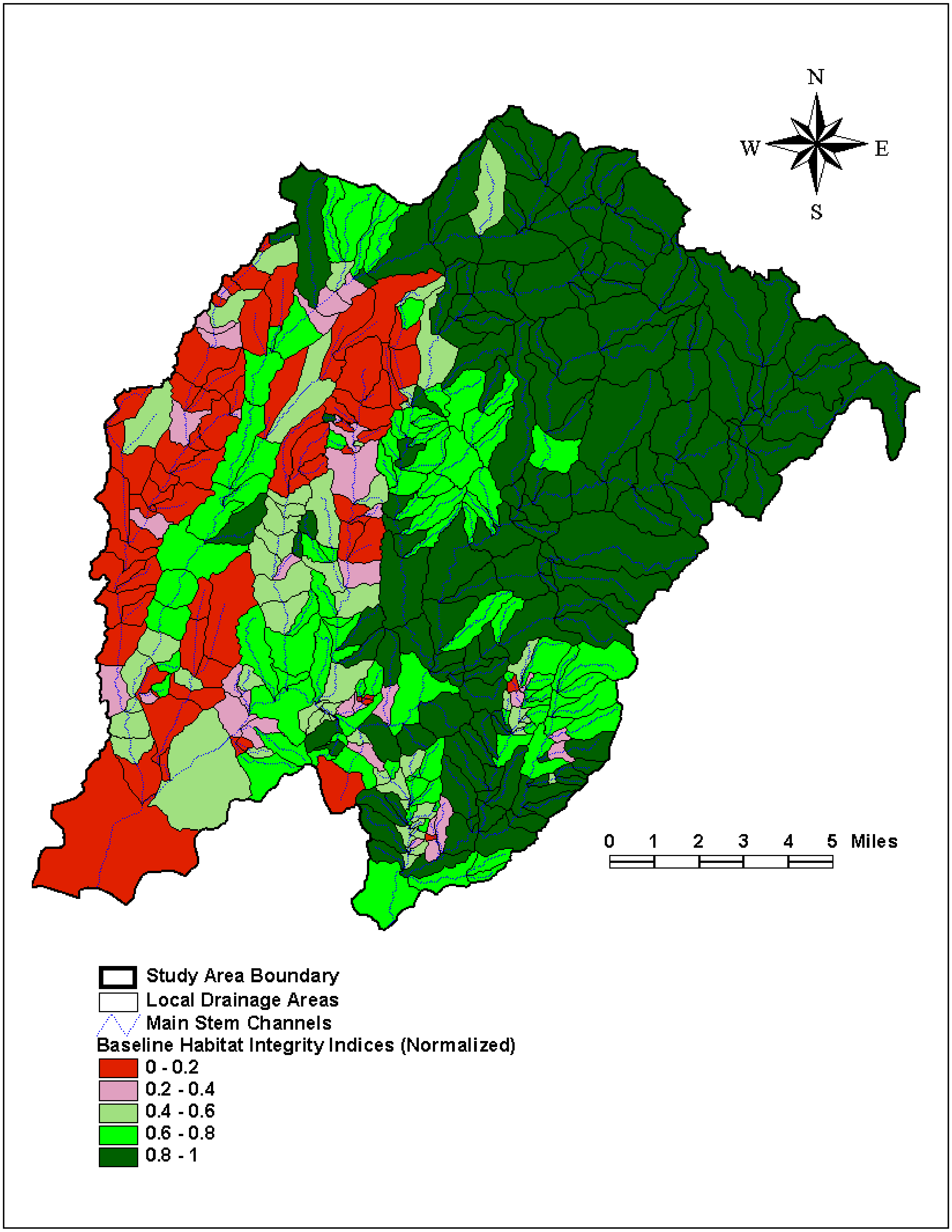

Figure 21. Normalized baseline habitat integrity indices for riparian reaches

One of the primary applications of the information developed during this study is to identify the specific riparian reaches where restoration will maximize the increase in riparian ecosystem integrity for the study area, given a specific set of criteria or objectives. To this end we conducted three of many possible restoration simulations. In the first simulation, the objective was to identify the riparian reaches where application of the restoration template would result in the maximum possible increase in riparian ecosystem integrity regardless of the level of effort required. Results from the first restoration simulation are shown as estimated changes in hydrologic (Figure 22), water quality (Figure 23), and habitat (Figure 24) integrity indices resulting from implementation of the recommended restoration template. This method of identifying riparian reaches for restoration would restore those riparian reaches that would result in the greatest increased integrity index scores without regard to level of effort.

In the second simulation, the objective was to identify the riparian reaches where application of the restoration template would result in the greatest increase in riparian ecosystem hydrologic (Figure 25), water quality (Figure 26), and habitat (Figure 27) integrity while considering the level of effort required. This simulation identified riparian reaches for restoration where the application of the recommended restoration template would result in the greatest increase of riparian ecosystem integrity per unit of effort. This method of selective restoration of riparian reaches will insure the maximum increase in riparian ecosystem integrity per unit of effort in the study area.

Unlike the first two simulations, which focused solely on modifications to the riparian ecosystems (i.e., channel geomorphic features, riparian vegetation, etc.) the area of consideration for the third simulation extended beyond the riparian ecosystem proper into adjacent upland areas, i.e., the local drainage area and the drainage basins of the riparian reachs. The objective of this simulation was to identify the riparian reaches where application of the restoration template modifications to the land uses in the local drainage area and drainage basin of the riparian reach. Specifically, in this simulation, areas of active or former rangeland land use were restored to native vegetation. Thus the resultant increase in the normalized hydrologic (Figure 28), water quality (Figure 29), and habitat (Figure 30) integrity indices reflect both the application of the recommended restoration template at the riparian reach scale and conversion of active or former rangelands to natural vegetation within the local drainage area and drainage basin.

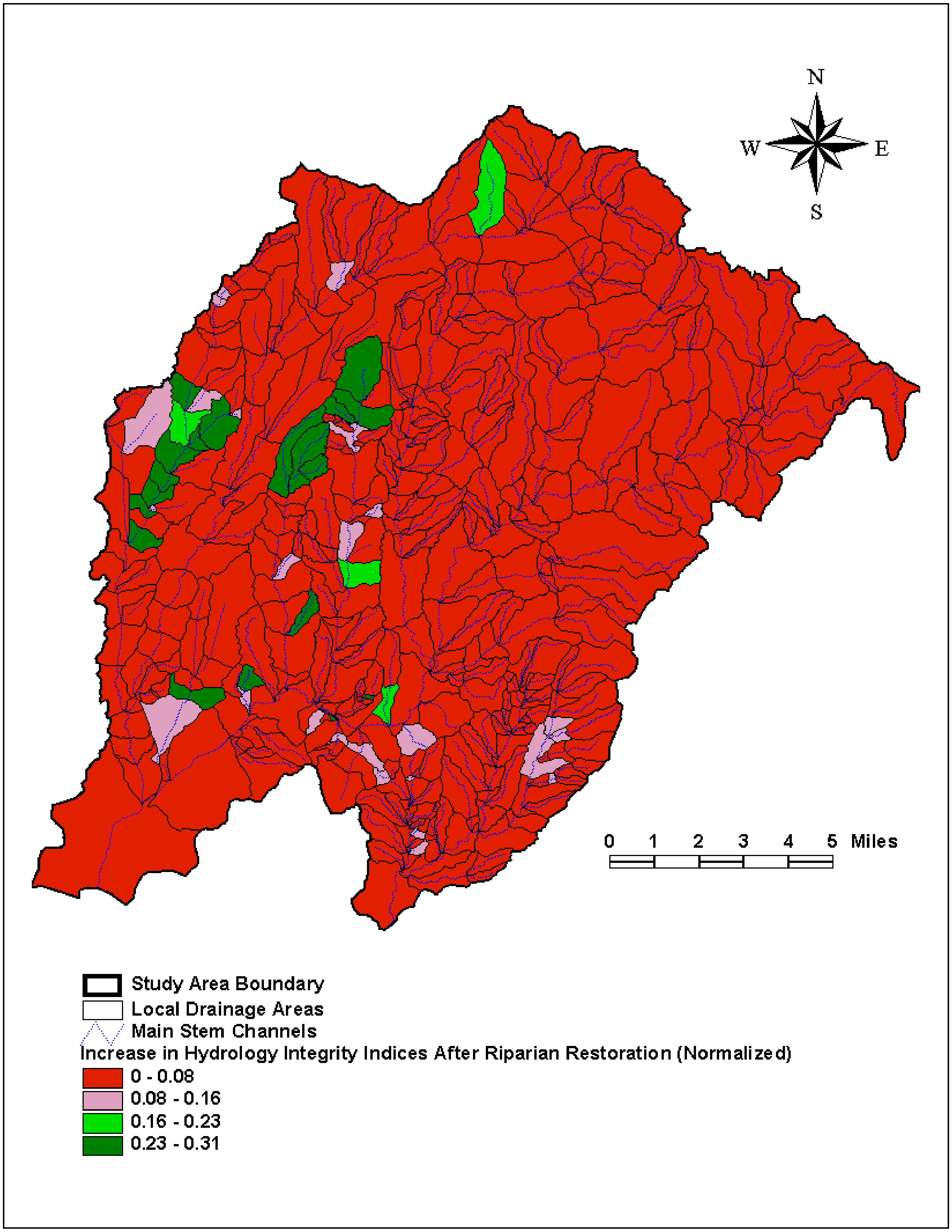

Figure 22. Increase in hydrologic integrity index for riparian reaches after simulated restoration

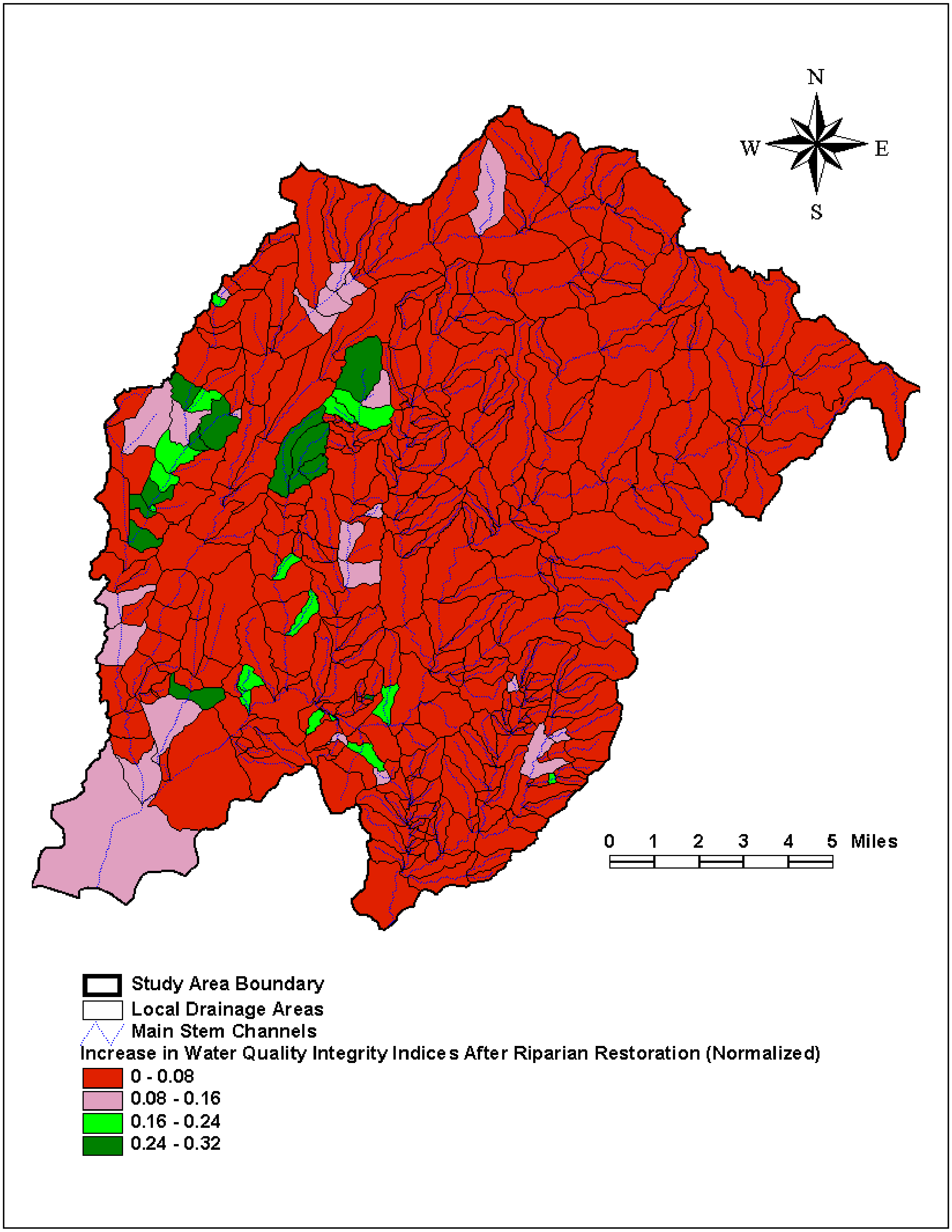

Figure 23. Increase in water quality integrity index for riparian reaches after simulated restoration

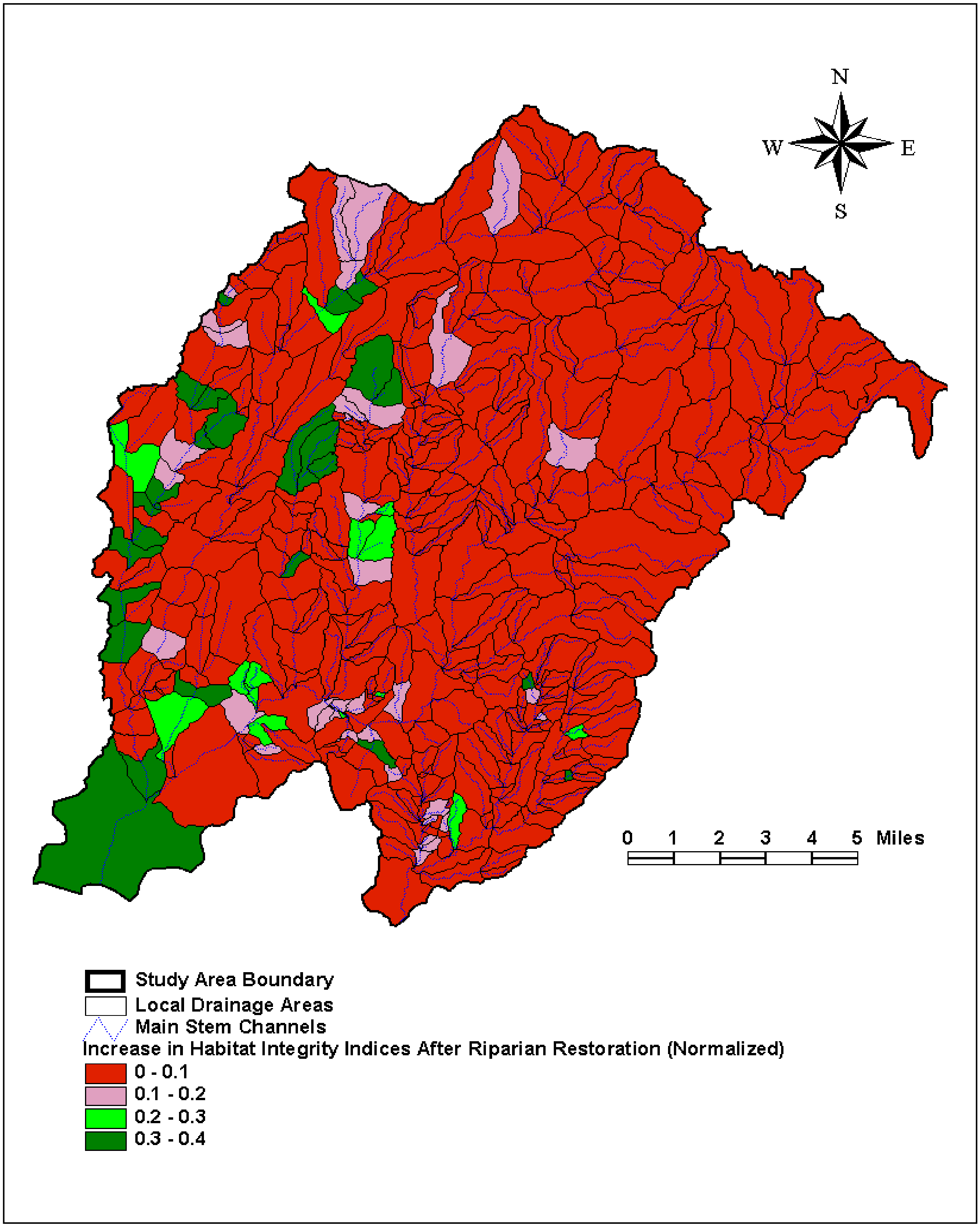

Figure 24. Increase in habitat integrity index for riparian reaches after simulated restoration

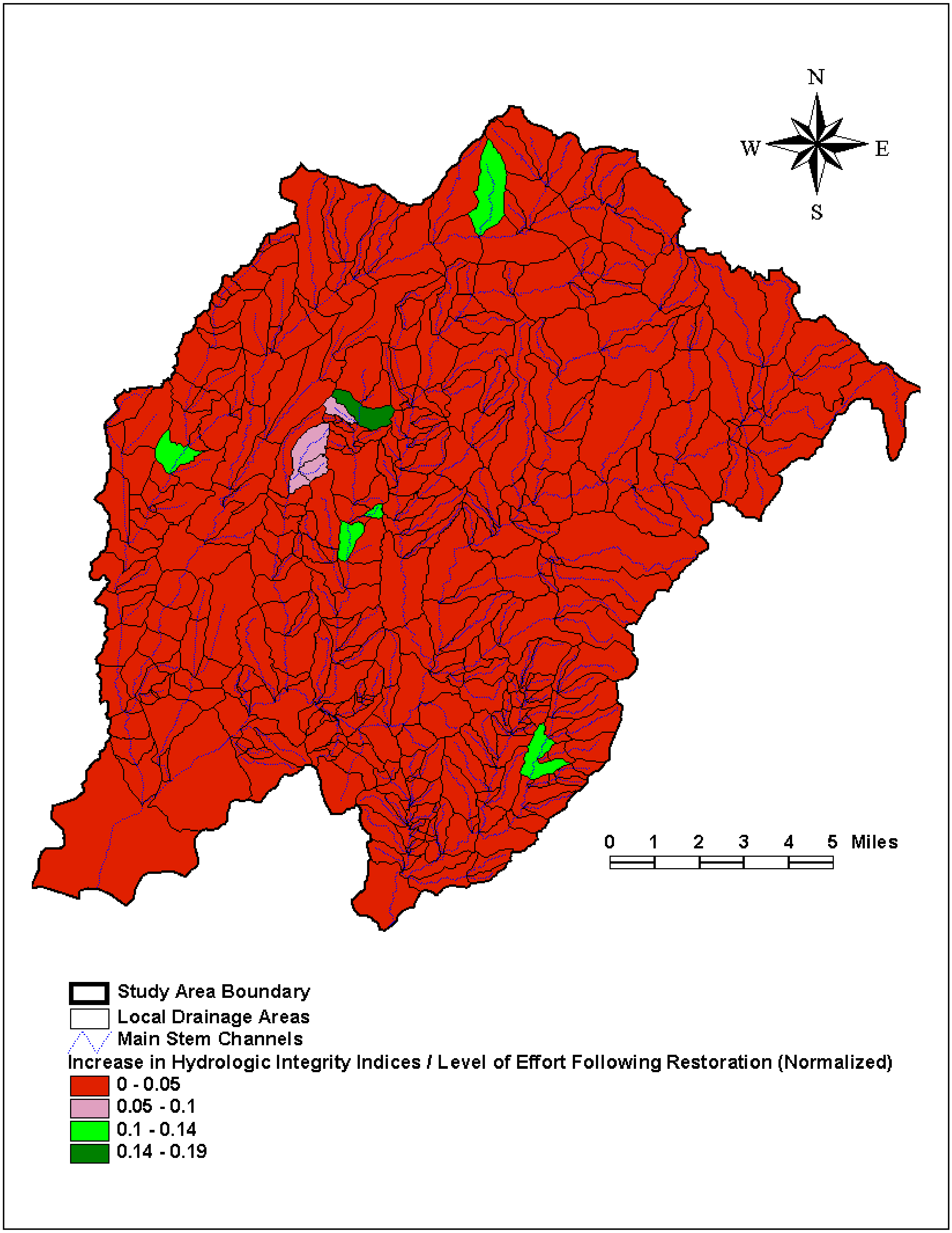

Figure 25. Increase in hydrologic integrity index / level-of-effort unit(s) for riparian reaches after simulated restoration

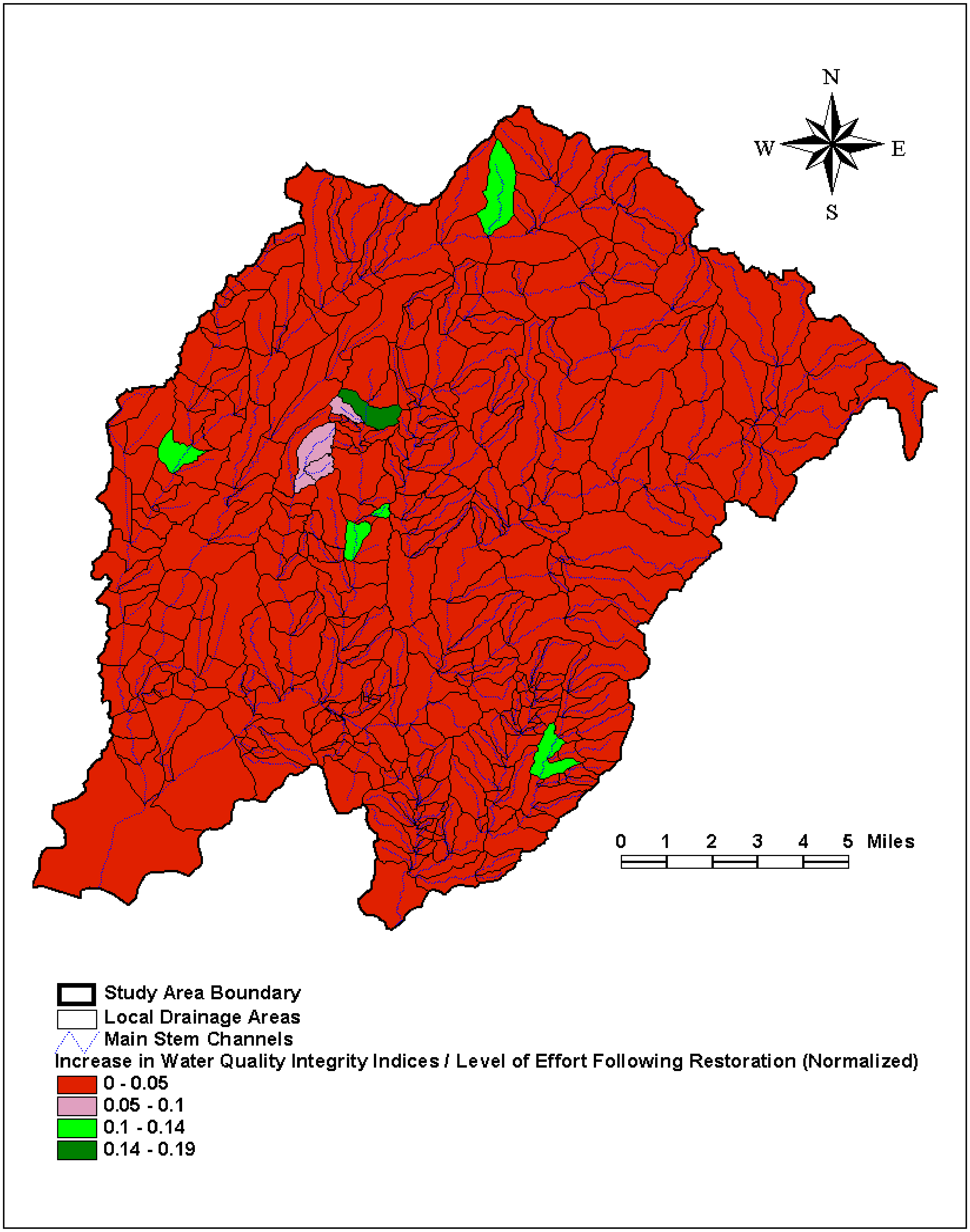

Figure 26. Increase in water quality integrity index / level-of-effort unit(s) for riparian reaches after simulated restoration

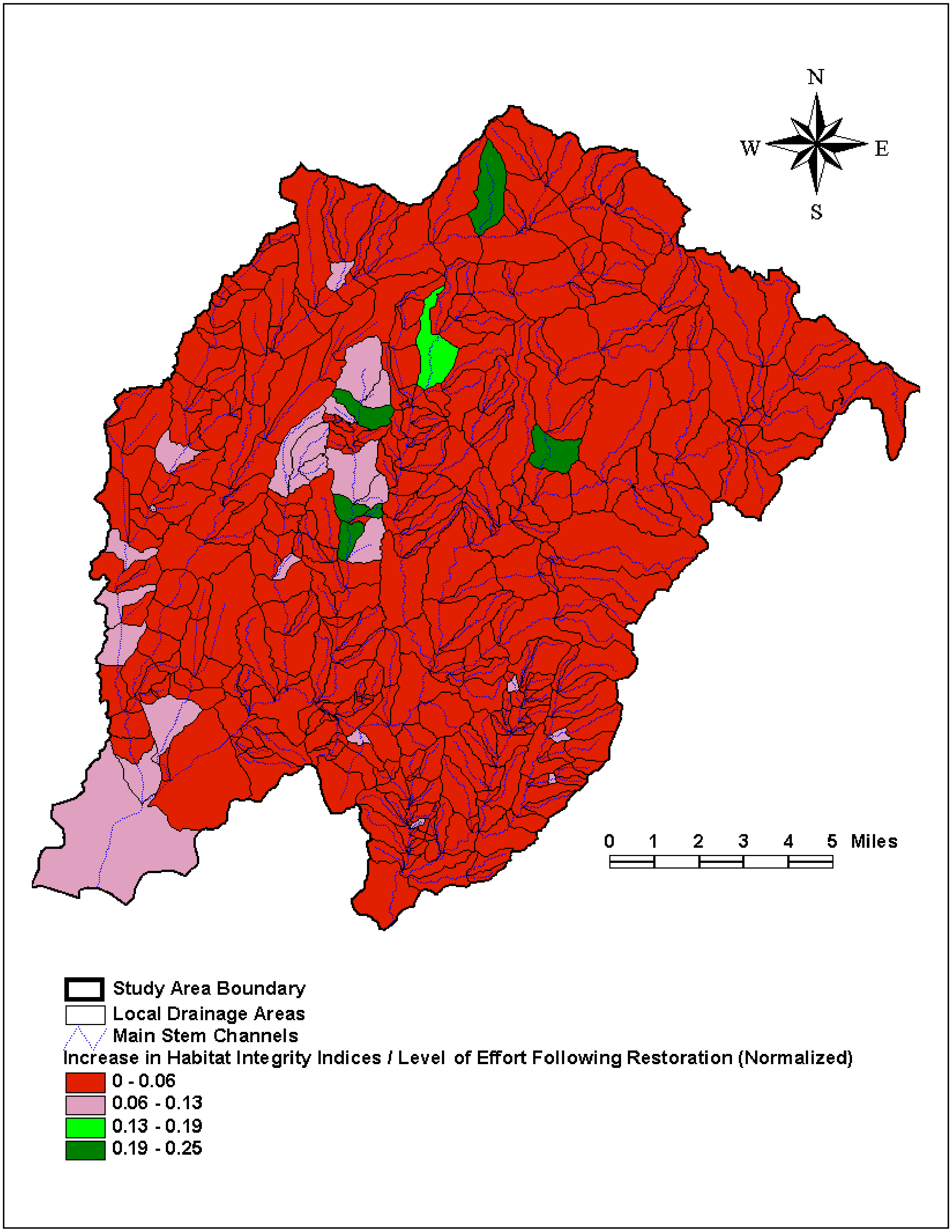

Figure 27. Increase in habitat integrity index / level-of-effort unit(s) for riparian reaches after simulated restoration

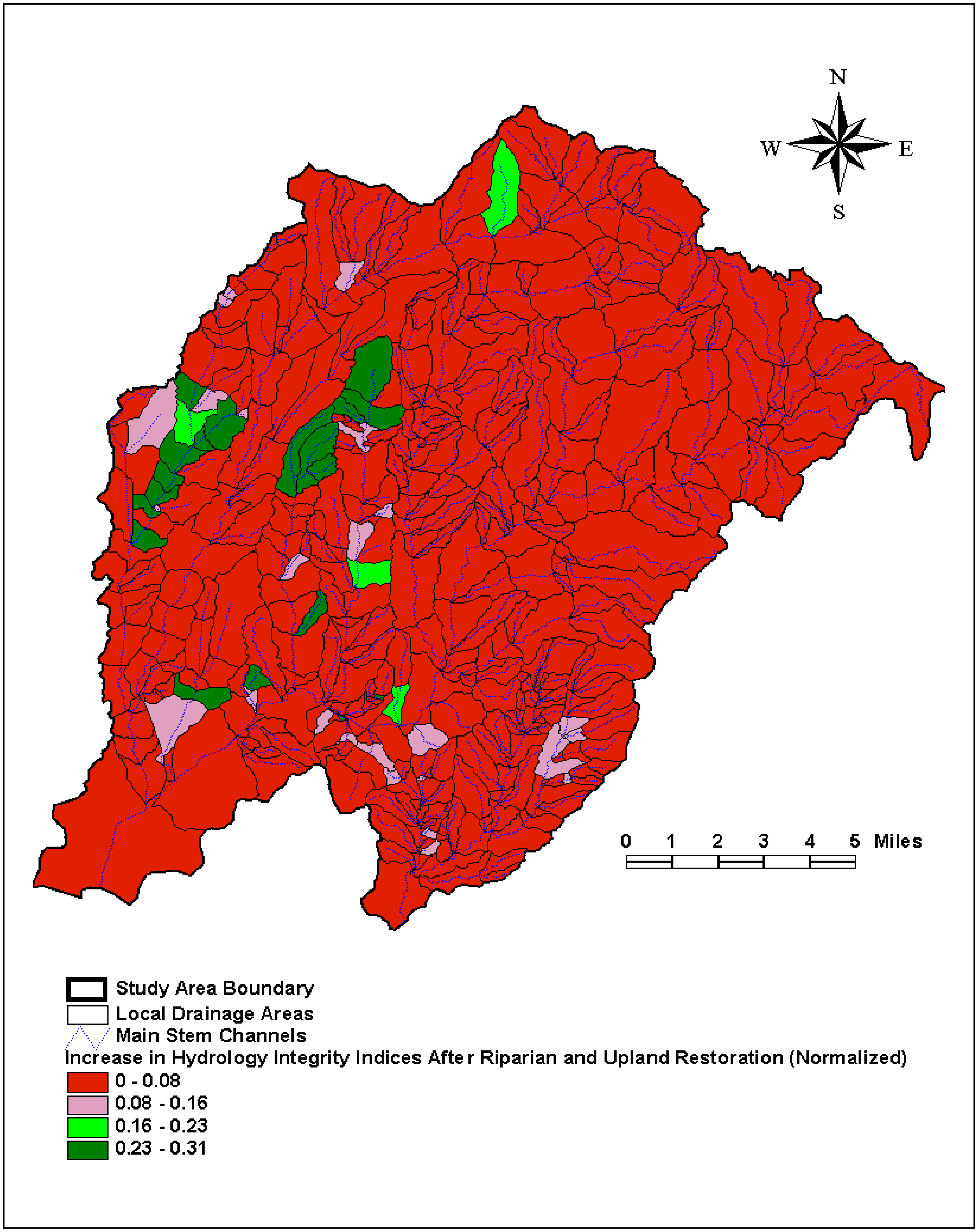

Figure 28. Increase in hydrologic integrity index after simulated restoration in riparian ecosystem and uplands in the drainage basin of the riparian reach

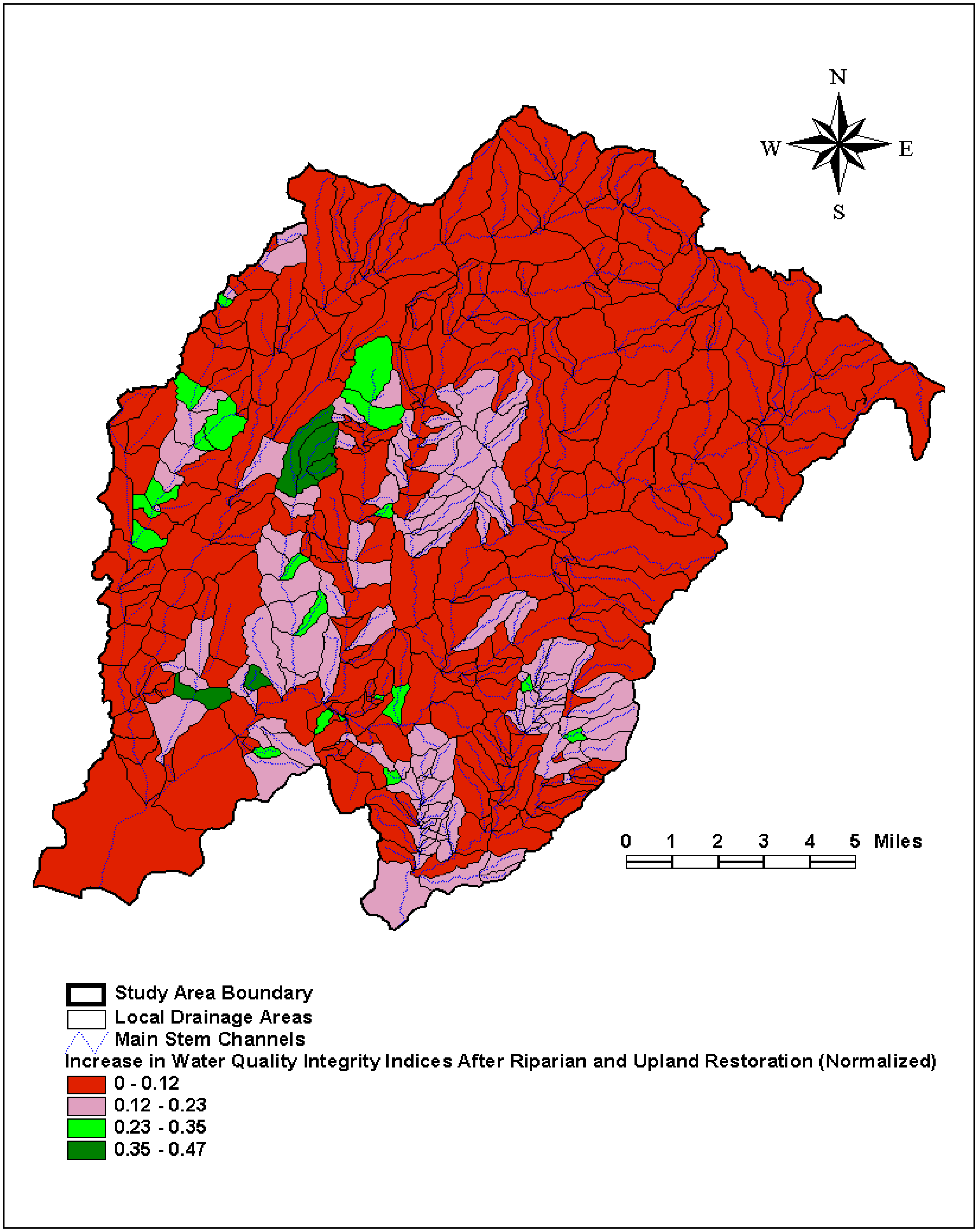

Figure 29. Increase in water quality integrity index after simulated restoration in riparian ecosystem and uplands in the drainage basin of the riparian reach

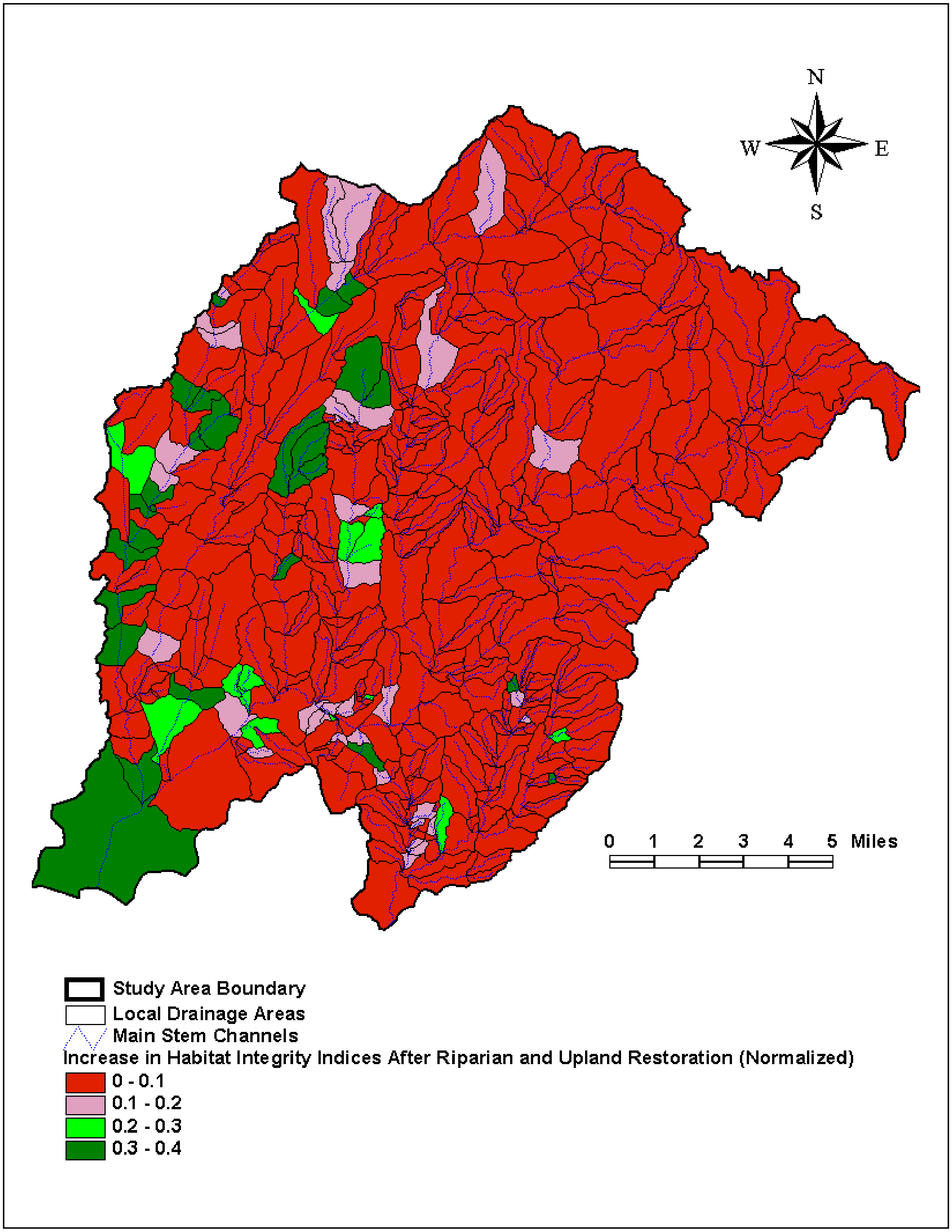

Figure 30. Increase in habitat integrity index after simulated restoration in riparian ecosystem and uplands in the drainage basin of the riparian reach

It is important to recognize that the three simulations presented herein represent only a small sample of the variety of simulations that are possible. Depending on restoration objectives, numerous variations for prioritizing reaches may be identified. For example, if the objective is to restore large patches (i.e., subasins) to facilitate habitat restoration for certain species, it would be possible to identify which of several candidate subasins would require the greatest level of effort to restore. Similarly, if the objective is to restore riparian corridors for the purpose of connecting existing large patches, it would be possible to identify which of several candidate riparian corridors would require the greatest level of effort to restore. Possible scenarios are limited only by the ability to identify specific objectives.

Finally, it is important to recognize that including restoration of upland habitats in the local drainage area and drainage basin of riparian reaches opens a vast array of other opportunities in terms of increasing the hydrologic, water quality, and habitat integrity indices of riparian reaches.

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Appendix A: ArcView Themes and Images, Spreadsheet, and Report Files

ArcView themes developed for this project are contained in folders on the attached CD. These folders and the shape files are described below. All shape files are in UTM NAD83, Zone 11, with meters as the map unit. The “xxx” designates the various ArcView extensions attached to shape files created for each theme (i.e., dbf, shp, shx).

Local Drainage Areas

The shape file for the local drainage area theme is contained in the “local drainages” folder. The shape file in this folder is named:

sjsm ld 10-24-03.xxx

Main Stem Channels

The shape file for the main stem and non-wetland waters stream channels theme is contained in the “mains and tribs” folder. The shape file in this folder is named:

sjsm mains 10-24-03.xxx

Miscellaneous

This folder contains various miscellaneous shape files used during some portion of the analysis. The file names with a description are as follows:

watershed mask.xxx (mask used to block out areas outside the study area)
sjsm geology.xxx (surficial geology from Morton et al. 1999)

Images

This folder contains aerial and digital raster graphic ArcView images for the San Diego Creek watershed. The aerial images are from US Air Photo, and were taken in February of 2002. The digital raster graphics image is from Sure Maps Raster. The names of files in this folder are:

sjsm 1-1.xxx
sjsm 1-2.xxx
sjsm 1-3.xxx
sjsm 1-4.xxx
sjsm 1-5.xxx
sjsm 1-6.xxx
sjsm 1-7.xxx
sjsm 1-8.xxx
sjsm 1-9.xxx

Spreadsheets

This folder contains a spreadsheet with data and analysis for the baseline assessment and restoration simulations discussed in this report. The spreadsheet file in this folder is named:

sjsm baseline and simulations 6-29-04.xls

Report

This folder contains two documents. The first is the final report in Microsoft Word format. The second is the final report in Adobe Acrobat format. The document files in this folder are named:

sjsm wr report 8-23-04.doc
sjsm wr report 8-23-04.pdf

Appendix B: PTYPE for the Preliminary digital geologic map of the Santa Ana 30' x 60' quadrangle, Southern California, Version 1

Internet Link: http://geo-nsdi.er.usgs.gov/metadata/open-file/99-172/metadata.faq.html)

Table 3. PTYPE descriptions for Preliminary Digital Geologic Map of Santa Ana

PTYPE	Definition
Qaf	Artificial fill (late Holocene)
Qw	Wash deposits (late Holocene)
Qf	Alluvial fan deposits (late Holocene)
Qa	Active axial channel deposits (late Holocene)
Qv	Active valley deposits (late Holocene)
Qc	Colluvium (late Holocene)
Qls	Landslide deposits (late Holocene)
Qe	Eolian deposits (late Holocene)
Qm	Marine deposits (late Holocene)
Qes	Estuarine deposits (late Holocene)
Ql	Lacustrine deposits (late Holocene)
Qlv	Lacustrine and fluvial deposits (late Holocene)
Qyw	Young alluvial wash deposits (Holocene and latest Pleistocene)
Qyf	Young alluvial fan deposits (Holocene and latest Pleistocene)
Qyf4	Young alluvial fan deposits, Unit 4 (late Holocene and latest Pleistocene)
Qyf3	Young alluvial fan deposits, Unit 3 (late and middle Holocene)
Qyf2	Young alluvial fan deposits, Unit 2 (early Holocene)
Qyf1	Young alluvial fan deposits, Unit 1 (early Holocene and late Pleistocene)
Qya	Young axial channel deposits (Holocene and latest Pleistocene)
Qyv	Young alluvial valley deposits (Holocene and late Pleistocene)
Qyv1	Young alluvial valley deposits, Unit 1 (early Holocene and late Pleistocene)
Qyls	Young landslide (Holocene and latest Pleistocene)

Table 3. cont.

Qye	Young eolian deposits (Holocene and latest Pleistocene)
Qypt	Young peat deposits (Holocene)
Qow	Old alluvial wash deposits (late to middle Pleistocene)
Qof	Old alluvial fan deposits (late to middle Pleistocene)
Qof1	Old alluvial fan deposits, Unit 1 (late to middle Pleistocene)
Qofv	Old alluvial fan deposits and young alluvial valley deposits (Holocene and late to middle Pleistocene)
Qoa	Old axial channel deposits (late to middle Pleistocene)
Qoa1	Old axial channel deposits, Unit 1 (middle Pleistocene)
Qov	Old alluvial valley deposits (late to middle Pleistocene)
Qoc	Old colluvial deposits (late to middle Pleistocene)
Qols	Old landslide deposits (late to middle Pleistocene)
Qom	Old marine deposits (late to middle Pleistocene)
Qvof	Very old alluvial fan deposits (middle to early Pleistocene)
Qvof2	Very old alluvial fan deposits, Unit 2 (early Pleistocene)
Qvof1	Very old alluvial fan deposits, Unit 1 (early Pleistocene)
Qvoa	Very old axial channel deposits (middle to early Pleistocene)
Qvoa2	Very old axial channel deposits, Unit 2 (early Pleistocene)
Qvoa1	Very old axial channel deposits, Unit 1 (early Pleistocene)
Qvols	Very old landslide deposits (middle to early Pleistocene)
Qvom	Very old marine deposits (middle to early Pleistocene)
Qr	Regolith (Pleistocene)
Qpf	Pauba Formation (Pleistocene)
Qpfs	Sandstone member
Qpff	Fanglomerate member
Qlh	La Habra Formation (Pleistocene)
Qch	Coyote Hills Formation (Pleistocene)

Table 3. cont.

Qsp	San Pedro Formation (Pleistocene)
QTsw	Sandstone unit: Sandstone and conglomerate of Wildomar area (Pleistocene and Pliocene)
QTcw	Conglomerate unit: Sandstone and conglomerate of Wildomar area (Pleistocene and Pliocene)
QTs	Unnamed late Cenozoic sedimentary rocks in Riverside and Corona areas (early Pleistocene to late Pliocene?)
QTt	Late Cenozoic conglomerate of Temescal area (early Pleistocene to late Pliocene?)
QTc	Conglomeratic sedimentary rocks of Riverside West 7.5' quadrangle (early Pleistocene to late Pliocene?)
QTn	Late Cenozoic sedimentary rocks of Norco area (early Pleistocene to late Pliocene?)
QTstu	Upper member (Pleistocene): San Timoteo beds of Frick (1921) (Pleistocene and Pliocene)
QTsts	Conglomeratic sandstone beds: San Timoteo beds of Frick (1921) (Pleistocene and Pliocene)
QTstc	Quartzite-bearing conglomerate beds: San Timoteo beds of Frick (1921) (Pleistocene and Pliocene)
Tstm	Middle member (Pliocene): San Timoteo beds of Frick (1921) (Pleistocene and Pliocene)
Tstl	Lower member (Pliocene): San Timoteo beds of Frick (1921) (Pleistocene and Pliocene)
Tta	Temecula Arkose (Pliocene)
Tf	Fernando Formation (Pliocene)
Tfu	Upper Member: Fernando Formation (Pliocene)
Tfl	Lower Member: Fernando Formation (Pliocene)
Tn	Niguel Formation (Pliocene)
Tns	Sandstone of Norco area (Pliocene)
Tc	Capistrano Formation (early Pliocene and Miocene)
Tco	Oso Member: Capistrano Formation (early Pliocene and Miocene)

Table 3. cont.

Tcs	Siltstone facies: Capistrano Formation (early Pliocene and Miocene)
Tmeus	Upper sandstone member (early Pliocene and Miocene): Mount Eden Formation of Fraser (1931) (early Pliocene and Miocene)
Tmem	Mudrock member (early Pliocene and Miocene): Mount Eden Formation of Fraser (1931) (early Pliocene and Miocene)
Tmels	Lower sandstone member (Miocene): Mount Eden Formation of Fraser (1931) (early Pliocene and Miocene)
Tmea	Arkosic sandstone member (Miocene): Mount Eden Formation of Fraser (1931) (early Pliocene and Miocene)
Tmec	Conglomeratic sandstone member (Miocene): Mount Eden Formation of Fraser (1931) (early Pliocene and Miocene)
Tch	Sandstone and conglomerate in southeastern Chino Hills (early Pliocene and Miocene)
Tp	Puente Formation (early Pliocene and Miocene)
Tpsc	Sycamore Canyon Member (early Pliocene and Miocene)
Tpy	Yorba Member (Miocene)
Tps	Soquel Member (Miocene)
Tplv	La Vida Member (Miocene)
Tlm	Lake Mathews Formation (Miocene)
Tcgr	Rhyolite clast conglomerate of Lake Mathews area (Miocene?)
Tcg	Conglomerate of Lake Mathews area (Miocene?)
Tm	Monterey Formation (Miocene)
Tvsr	Santa Rosa basalt of Mann (1955) (Miocene)
Tvt	Basalt of Temecula area (Miocene)
Tvh	Basalt of Hogbacks (Miocene)
Tvep	Basalt of Elsinore Peak (Miocene)
Tsob	San Onofre Breccia (middle Miocene)
Tt	Topanga Formation (middle Miocene)
Ttp	Paulerino Member: Topanga Formation (middle Miocene)

Table 3. cont.

Ttlt	Los Trancos Member: Topanga Formation (middle Miocene)
Ttb	Bommer Member: Topanga Formation (middle Miocene)
Tvem	El Modeno Volcanics (middle Miocene)
Tvema	Andesitic volcanic rocks: El Modeno Volcanics (middle Miocene)
Tvemt	Tuff and tuff breccia: El Modeno Volcanics (middle Miocene)
Tvemb	Basalt: El Modeno Volcanics (middle Miocene)
Ta	Andesitic intrusive rocks (middle Miocene): Volcanic intrusive rocks associated with El Modeno Volcanics (middle Miocene)
Td	Diabase intrusive rocks (middle Miocene): Volcanic intrusive rocks associated with El Modeno Volcanics (middle Miocene)
Tvss	Vaqueros, Sespe, Santiago, and Silverado Formations, undivided (early Miocene, Oligocene, and Paleocene)
Tv	Vaqueros Formation (early Miocene, Oligocene, and late Eocene)
Ts	Sespe Formation (early Miocene, Oligocene, and late Eocene)
Tvs	Sespe and Vaqueros Formations, undifferentiated (early Miocene, Oligocene, and late Eocene)
Tcga	Conglomerate of Arlington Mountain (Paleogene?)
Tep	Sandstone of Elsinore Peak (Paleogene?)
Tsa	Santiago Formation (middle Eocene)
Tsi	Silverado Formation (Paleocene)
Kwl	Williams and Ladd Formations, undifferentiated (upper Cretaceous)
Kw	Williams Formation (upper Cretaceous)
Kwps	Pleasants Sandstone Member: Williams Formation (upper Cretaceous)
Kwsr	Schulz Ranch Sandstone Member: Williams Formation (upper Cretaceous)
Kwst	Starr Member: Williams Formation (upper Cretaceous)
Kl	Ladd Formation (upper Cretaceous)
Klhs	Holz Shale Member: Ladd Formation (upper Cretaceous)
Klbc	Baker Canyon Conglomerate Member (upper Cretaceous): Ladd Formation (upper Cretaceous)

Table 3. cont.

Ktr	Trabuco Formation (upper Cretaceous)
Klct	Tonalite of Lamb Canyon (Cretaceous)
Kmeg	Granite of Mount Eden (Cretaceous)
Kthgd	Granodiorite of Tucalota Hills (Cretaceous)
Klt	Tonalite near mouth of Laborde Canyon (Cretaceous)
Khqd	Hypersthene quartz diorite (Cretaceous)
Ktcg	Monzogranite of Tres Cerritos (Cretaceous)
Kp	Pegmatite dikes: Lakeview Mountains pluton (Cretaceous)
Klmt	Tonalite: Lakeview Mountains pluton (Cretaceous)
Klml	Leucocratic rocks: Lakeview Mountains pluton (Cretaceous)
Klmm	Melanocratic rocks: Lakeview Mountains pluton (Cretaceous)
Klmc	Comb-layered gabbro: Lakeview Mountains pluton (Cretaceous)
Klmg	Hypersthene hornblende gabbro: Lakeview Mountains pluton (Cretaceous)
Klmtg	Lakeview Mountains tonalite and granodiorite, undifferentiated: Lakeview Mountains pluton (Cretaceous)
Krct	Tonalite of Reinhardt Canyon pluton (Cretaceous)
Kbpg	Monzogranite of Bernasconi Pass (Cretaceous)
Kbpm	Migmatitic rock within Monzogranite of Bernasconi Pass: Monzogranite of Bernasconi Pass (Cretaceous)
Ktbh	Tonalite of Bernasconi Hills (Cretaceous)
Kp	Granitic pegmatite dikes: Box Springs plutonic complex (Cretaceous)
Kbt	Biotite tonalite: Box Springs plutonic complex (Cretaceous)
Kbfg	Biotite granodiorite and tonalite: Box Springs plutonic complex (Cretaceous)
Kbfgi	Biotite granodiorite and tonalite containing abundant inclusions: Box Springs plutonic complex (Cretaceous)
Kbhg	Heterogeneous porphyritic granodiorite: Box Springs plutonic complex (Cretaceous)
Kbhgl	Layered heterogeneous porphyritic granodiorite: Box Springs plutonic complex (Cretaceous)

Table 3. cont.

Kbg	Porphyritic granodiorite: Box Springs plutonic complex (Cretaceous)
Kbft	Biotite-hornblende tonalite: Box Springs plutonic complex (Cretaceous)
Kbht	Heterogeneous biotite tonalite: Box Springs plutonic complex (Cretaceous)
Kbgt	Heterogeneous granodiorite and tonalite: Box Springs plutonic complex (Cretaceous)
Kba	Amphibolitic gabbro: Box Springs plutonic complex (Cretaceous)
Kvt	Val Verde tonalite: Val Verde pluton (Cretaceous)
Kvtk	Potassium feldspar-bearing tonalite: Val Verde pluton (Cretaceous)
Kvti	Inclusion-rich tonalite: Val Verde pluton (Cretaceous)
Kgr	Granophyre (Cretaceous)
Kgab	Heterogeneous mixture of olivine, pyroxene, and hornblende gabbros: Green Acres gabbro complex (Cretaceous)
Kgao	Olivine gabbro: Green Acres gabbro complex (Cretaceous)
Kgah	Hornblende-rich gabbro: Green Acres gabbro complex (Cretaceous)
Kgat	Troctolite: Green Acres gabbro complex (Cretaceous)
Kgaa	Anorthositic gabbro: Green Acres gabbro complex (Cretaceous)
Kgam	Metagabbro: Green Acres gabbro complex (Cretaceous)
Kgg	Hypersthene monzogranite: Gavilan ring complex (Cretaceous)
Kgt	Massive textured tonalite: Gavilan ring complex (Cretaceous)
Kgtf	Foliated tonalite: Gavilan ring complex (Cretaceous)
Kgti	Tonalite containing abundant mesocratic inclusions: Gavilan ring complex (Cretaceous)
Kgh	Hypabyssal tonalite: Gavilan ring complex (Cretaceous)
Kgct	Coarse-grained biotite-hornblende tonalite: Gavilan ring complex (Cretaceous)
Kght	Heterogeneous tonalite: Gavilan ring complex (Cretaceous)
Kmp	Micropegmatite granite (Cretaceous)
Kmpc	Micropegmatite and granodiorite of Cajalco pluton, undifferentiated (Cretaceous)
Ktd	Tonalite dikes of Mount Rubidoux (Cretaceous)

Table 3. cont.

Kmrg	Granite of Mount Rubidoux (Cretaceous)
Krg	Granite of the Riverside area (Cretaceous)
Kmhg	Mount Hole Granodiorite (Cretaceous)
Klst	La Sierra Tonalite (Cretaceous)
Katg	Granodiorite of Arroyo del Toro pluton (Cretaceous)
Kcto	Tourmalized monzogranite and granodiorite: Cajalco pluton (Cretaceous)
Kcg	Monzogranite: Cajalco pluton (Cretaceous)
Kcgd	Granodiorite: Cajalco pluton (Cretaceous)
Kct	Tonalite: Cajalco pluton (Cretaceous)
Kcgq	Granodiorite and quartz latite, undifferentiated: Cajalco pluton (Cretaceous)
Kcgb	Granodiorite and gabbro, undifferentiated: Cajalco pluton (Cretaceous)
Kld	Quartz latite dikes: Domenigoni Valley pluton (Cretaceous)
Kdvg	Granodiorite to tonalite of Domenigoni Valley: Domenigoni Valley pluton (Cretaceous)
Kgbf	Fine grained hornblende gabbro, Railroad Canyon area (Cretaceous): Domenigoni Valley pluton (Cretaceous)
Kpvgr	Granophyre: Paloma Valley Ring Complex (Cretaceous)
Kp	Pegmatite dikes of Paloma Valley Ring Complex: Paloma Valley Ring Complex (Cretaceous)
Kpvg	Monzogranite to granodiorite: Paloma Valley Ring Complex (Cretaceous)
Kpvt	Tonalite: Paloma Valley Ring Complex (Cretaceous)
Kpvgb	Granodiorite and gabbro, undivided: Paloma Valley Ring Complex (Cretaceous)
Ksmg	Monzogranite of Squaw Mountain (Cretaceous)
Kts	Tonalite of Slaughterhouse Canyon (Cretaceous)
Kp	Granitic Pegmatite dikes (Cretaceous)
Kg	Granitic dikes. (Cretaceous)
Kgu	Undifferentiated granite (Cretaceous
Kgd	Granodiorite, undifferentiated (Cretaceous)

Table 3. cont.

Kt	Tonalite, undifferentiated (Cretaceous)
Ktm	Tonalite and mafic rock, undifferentiated (Cretaceous)
Kqd	Quartz diorite (Cretaceous)
Kdqd	Diorite and quartz diorite, undifferentiated (Cretaceous)
Kd	Diorite, undifferentiated (Cretaceous)
Kgb	Gabbro (Cretaceous)
Khg	Heterogeneous granitic rocks (Cretaceous)
Ks	Serpentinite (Cretaceous)
Kc	Carbonate-silicate rock (Cretaceous)
Kvsp	Santiago Peak Volcanics (Cretaceous)
Kvspi	Intrusive rocks associated with Santiago Peak Volcanics (Cretaceous)
Kvem	Estelle Mountain volcanics of Herzig (1991) (Cretaceous)
Kvr	Rhyolite of Estelle Mountains volcanics of Herzig (1991) (Cretaceous)
Ksv	Intermixed Estelle Mountain volcanics of Herzig (1991) and Cretaceous(?) sedimentary rocks (Cretaceous?)
Kvs	Intermixed Estelle Mountain volcanics of Herzig (1991) and Mesozoic sedimentary rocks (Mesozoic)
Mzmg	Mylonitic and cataclastic granitic rocks: Deformed granitic rocks of Transverse Ranges Province (Mesozoic)
Mzd	Diorite: Deformed granitic rocks of Transverse Ranges Province (Mesozoic)
Jbc	Bedford Canyon Formation (Jurassic)
Jbm	Marble (limestone)
Mzu	Mesozoic metasedimentary rocks, undifferentiated (Mesozoic)
Mzg	Graywacke (Mesozoic)
Mzq	Quartz-rich rocks (Mesozoic)
Mzqg	Intermixed quartzite and graywacke (Mesozoic)
Mzgp	Intermixed graywacke and phyllite (Mesozoic)
Mzp	Phyllite (Mesozoic)

Table 3. cont.

Mzs	Schist (Mesozoic)
Mzm	Marble (Mesozoic)
Mzi	Interlayered phyllite (or schist) and quartzite (Mesozoic)
Mzds	Metadunite and serpentinite (Mesozoic)
Mzdx	Amphibole- and pyroxene-bearing rocks associated with metadunite-serpentinite (Mesozoic)
Mzdc	Marble associated with metadunite (Mesozoic)
Mzmn	Manganese-bearing rocks (Mesozoic)
Pzu	Paleozoic(?) rocks, undifferentiated (Paleozoic?)
Pzs	Biotite Schist (Paleozoic?)
Pzq	Impure quartzite (Paleozoic?)
Pzm	Marble (Paleozoic?)
Pzc	Calc-silicate rocks (Paleozoic?)
Pzms	Marble and schist, undivided (Paleozoic?)
Pza	Amphibolite (Paleozoic?)
KgMz	Intermixed Mesozoic schist and Cretaceous granitic rocks (Mesozoic)
KgPz	Intermixed Paleozoic(?) schist and Cretaceous granitic rocks (Mesozoic and Paleozoic?)