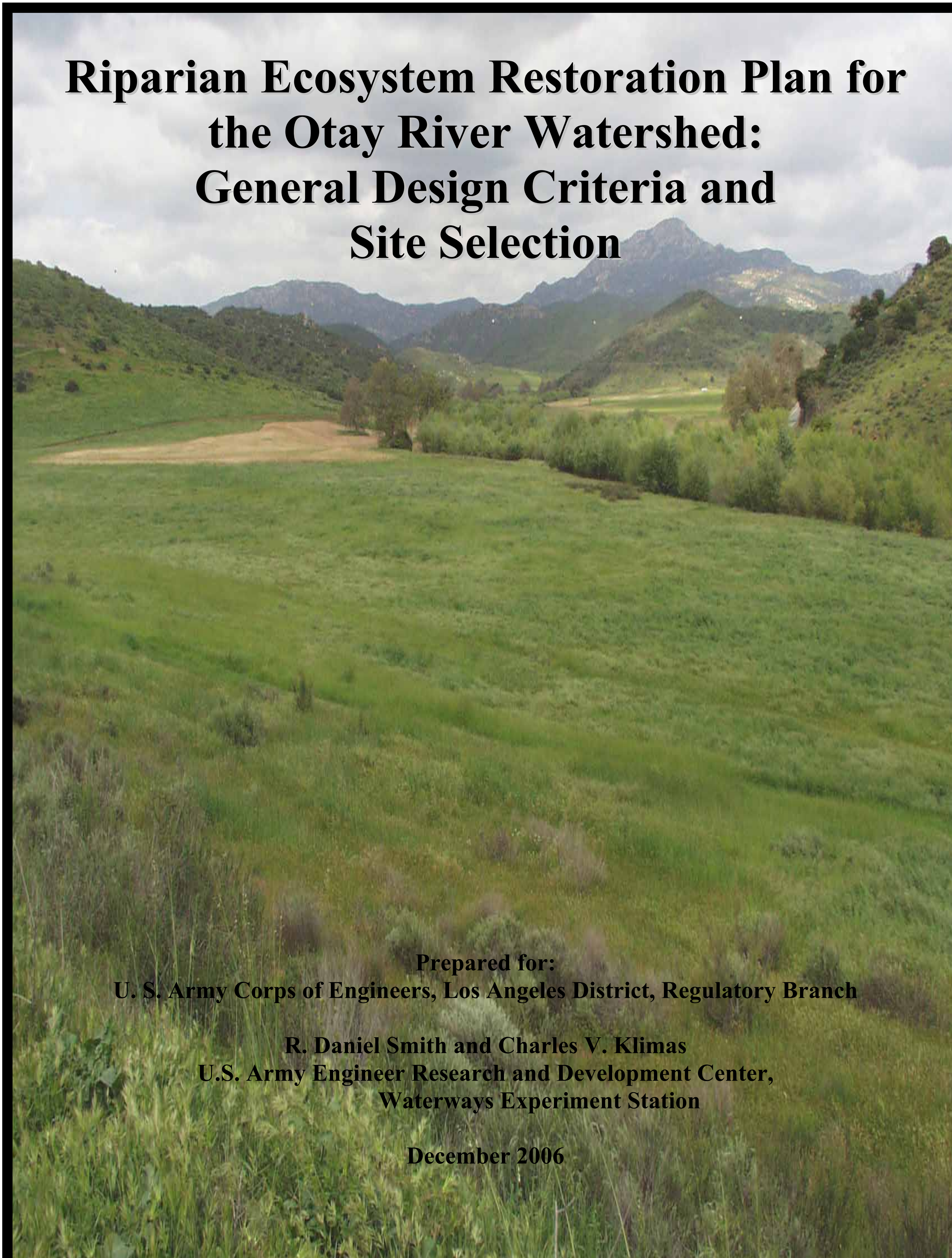
Riparian Ecosystem Restoration Plan for the Otay River Watershed: General Design Criteria and Site Selection



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

R. Daniel Smith and Charles V. Klimas
U.S. Army Engineer Research and Development Center,
Waterways Experiment Station

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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 Otay River watershed in 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" (Los Angeles District Corps of Engineers 1999). Several studies have been conducted in support of the SAMP including delineation of aquatic resources using a unique planning level delineation procedure (Lichvar et.al. 2003), and a baseline assessment of riparian ecosystem integrity (Smith 2004). This report describes a planning tool intended for use with the baseline assessment to help identify riparian restoration opportunities within the Otay River watershed.

The objective of the Watershed Restoration Plan is to facilitate development of an aquatic resources management program in the Otay River watershed through an evaluation of the potential for restoring the 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 here constitutes a flexible planning tool that is adaptable to changes in on-the ground conditions, data quality, project priorities, and similar eventualities.

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1.0 Introduction and Background

The Los Angeles District Corps of Engineers - Regulatory Branch is developing a Special Area Management Plan (SAMP) for the Otay River watershed. The SAMP is being conducted in coordination with the existing and proposed amendment to the Multiple Species Conservation Program (MSCP). 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" (Los Angeles District Corps of Engineers 1999).

A number of studies have been conducted in support of the SAMP. These include a watershed wide delineation of aquatic resources using a unique planning level delineation procedure (Lichvar et.al. 2003), and a baseline assessment of riparian ecosystem integrity (Smith 2004). For the baseline assessment riparian ecosystems were defined as linear corridors of variable width that occur along perennial, intermittent, and ephemeral streams that exhibit distinctive geomorphic features and vegetation communities in response to periodic exchange of surface and ground water between the stream channel and adjacent areas. Due to the large size of the watershed, inherent variability of riparian ecosystems, and differential nature of historical impacts to riparian ecosystems, the initial task in the baseline assessment was to delineate the riparian ecosystems into relatively homogenous assessment units called "riparian reaches." Riparian reaches were defined as discrete segments of the mainstem, bankfull stream channel, and the adjacent riparian ecosystem that were relatively homogenous with respect to geology, geomorphology, channel morphology, substrate type, vegetation communities, and cultural alteration. Each riparian reach unit 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 contributing to tributary, groundwater, and overland flow that directly enters the riparian reach), and the drainage basin (area contributing to mainstem inflow from upstream of a riparian reach). Indicators were scaled to a reference condition and then combined into indices for hydrologic, water quality, and habitat integrity.

Information from the delineation and baseline assessment is currently being used in two additional SAMP studies. The first is an alternatives analysis in which a variety of proposed alternatives are being analyzed to identify the level of impact each alternative will have on aquatic resources in the Otay River watershed. The second is the development of a Restoration Plan for riparian ecosystems in the watershed, the subject of this report.

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 management program in the Otay River watershed. In particular, this tool is intended to 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. Such an application 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 potential. This is the subject of this report. 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, it was necessary to devise specific categories of "restoration potential" and "level-of-effort" that could be applied consistently 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 stream 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 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 or buildings as a restoration option; however, changes in land use from rangeland and agriculture to natural vegetation is included as a potential restoration tool.

In addition to "restoration potential" we also developed a simple relative index of the resources required to restore a riparian ecosystem to its full potential. This "level-of-effort" index 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 be able 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, a level-of-effort estimate is assigned to each stream segment as a crude surrogate of construction and planting costs per unit area within the immediate riparian zone. 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 unusual circumstances and unforeseen factors that could significantly change the estimates.

The approach allows consideration of restoration effectiveness at several scales (reach, local drainage, 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 improvement 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 145 mi^2 Otay River watershed is located in San Diego County in southern California (Figure 1). Topography of the watershed ranges from rugged peaks typical of the Peninsular Range through rolling foothills, plateaus, and broad drainages flanked by alluvial terraces, to a flat coastal plain. The total elevation range is nearly 4000 feet. The mountains are primarily granitic, but the lower basin is dominated by marine terraces that range from flat to highly dissected, and the major stream valleys often have extensive alluvial terraces flanking the modern floodplain. Both the coastal terraces and the alluvial terraces often are partly buried by alluvial fan deposits (Strand 1962, Aspen Environmental Group 2004).

A Mediterranean climate of warm dry summers and mild winters predominates in the study area. Precipitation patterns vary with elevation and distance from the coast. The coastal zone receives about 13 inches of rain annually, and the average precipitation within the mountains is about 25 inches. Most rainfall and periods of high runoff occur between November and April, and many streams are dry during the summer and fall (Bowman 1973). Storm systems capable of delivering large amounts of rainfall occur periodically, and more than a dozen major floods were recorded in the region during the 20th century (Aspen Environmental Group 2004).

Natural plant communities of the uplands in the Otay watershed are predominantly coastal sage scrub and chaparral, which occur throughout the foothills and on most mountain slopes. Native grasslands, once fairly extensive along the Otay River valley and lower hillslopes, have largely been displaced by non-native annual grasses and forbs. Oak woodlands occur on north-facing slopes and in ravines throughout the watershed, and on some alluvial terraces and colluvial fans. Conifer forests are limited in distribution, but include fairly extensive stands of Tecate cypress on Otay Mountain in the southeastern portion of the watershed (Miles and Goudey 2003, Aspen Environmental Group 2004).

Wetland and riparian communities are quite variable within the study area. Wetlands include salt marsh and estuarine marsh on the coast, freshwater marshes within impoundments such as the Upper and Lower Otay Lakes, and scattered small wet meadows, vernal pools, and seeps. Riparian woodlands of sycamore and alder occur in mountain and foothill valleys with boulder and cobble substrates, and are frequently flanked by discontinuous oak woodlands on terraces and colluvial slopes. Larger valley bottoms and canyons include cottonwoods as an important component, along with sycamore and various willow species. Small sandy or steep channels and many areas where native canopy trees have been removed characteristically support thickets of willow and mulefat. Exotic species, particularly tamarisk, are commonly present in disturbed riparian areas and are dominant on many sites.

Periodic wildfire is an important factor in the maintenance of community structure and diversity in all upland habitat types in the region, particularly chaparral. There is considerable uncertainty regarding how fire patterns (frequency, intensity, and size of fires) may have changed during historic times, but fire continues to be a major influence on natural systems within the study area (Stephenson and Calcarone 1999, Keeley 2002). In October 2003, a series of fires burned approximately 27,000 acres in the Otay watershed (Aspen Environmental Group 2004). The field data compiled to produce this report were collected prior to those events.

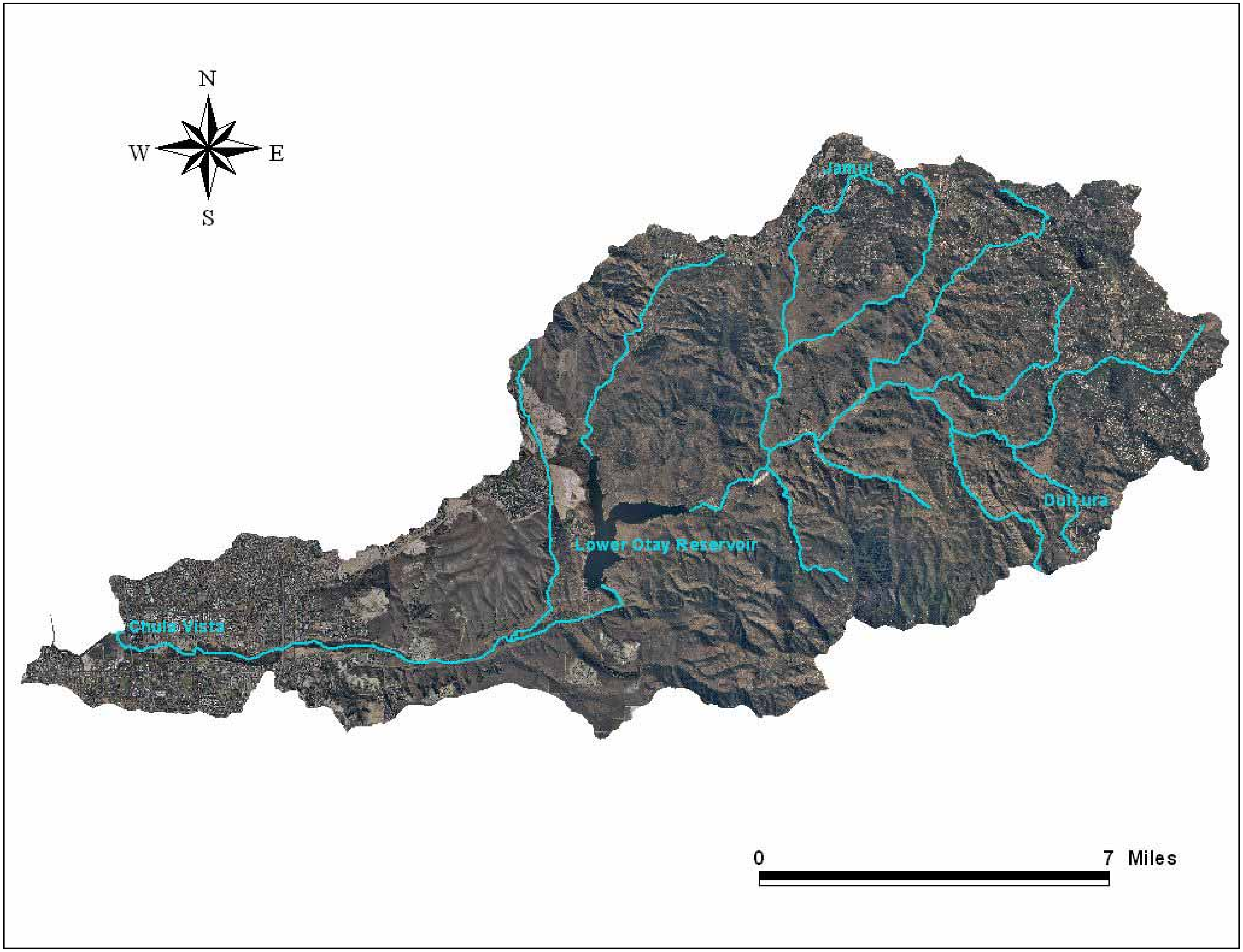

Figure 1. Study area boundaries in the Otay River watershed

The modern landscape of the Otay River watershed reflects extensive human influences. Early Spanish explorers observed that the Native American tribes in the region actively burned shrublands, but otherwise the indigenous people presumably had minimal impact. However, with the establishment of Spanish missions and large ranches, 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 (California Coastal Conservancy 2001).

After the area became part of the United States in 1848, the human population increased rapidly as a result of land booms and gold rushes, Over the following decades the city of San Diego and its port and rail facilities attracted new residents, industries and military bases that spread over much of the former ranch and farm land in the lower watershed. Development continued through the 20th century, with a concurrent reduction in agricultural land (Aspen Environmental Group 2004).

One of the major concerns in the region since the arrival of European farmers has been the availability of water. Two water supply reservoirs, the Upper and Lower Otay Lakes, currently provide water to San Diego. The Otay River and the Sweetwater River to the north were historically the principal sources of freshwater for San Diego Bay, but dams and extensive groundwater use have reduced their input by 76%. Changes in surface and subsurface water flows have likely reduced the potential extent of riparian plant communities and promoted the expansion of populations of invasive exotic species.

Today, approximately 20% of the Otay watershed is urban or residential. While population growth has been concentrated in the coastal region, residential development in more remote areas has been increasing rapidly. Various public and private land units are protected or managed primarily to benefit wildlife and other natural resources, including the Otay National Cooperative Land and Wildlife Management Area, the Otay Mountain Wilderness, the San Diego National Wildlife Refuge, and the Rancho Jamul Ecological Reserve. Other projects are underway or being considered to create reserves and parks and reduce the environmental impacts of the anticipated population growth.

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 2004). Adopting the riparian reaches as the units of evaluation allowed us to assess the effects of proposed restoration on riparian ecosystem integrity using the same methods and criteria employed during the baseline assessment, and allowed us to use the extensive database of reach characteristics collected during the baseline assessment. Two hundred and sixty-nine riparian reaches were identified in the Otay watershed.

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 2). Associated with each riparian reach was a local drainage which consisted of the area from which surface water drained directly to the riparian reach, and a drainage basin which consisted of the local drainages of all upstream riparian reaches. Land use and hydrologic characteristics were recorded for each of the local drainage areas as part of the baseline assessment.

In order to assess 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. The zone, template, and effort designations were made based on field characterizations of specific reach cross-sections supplemented by aerial photography and the detailed reach 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) and Rosgen (1996). However, some definitions have been framed in terms specific to the Otay River watershed and the objectives of this study.

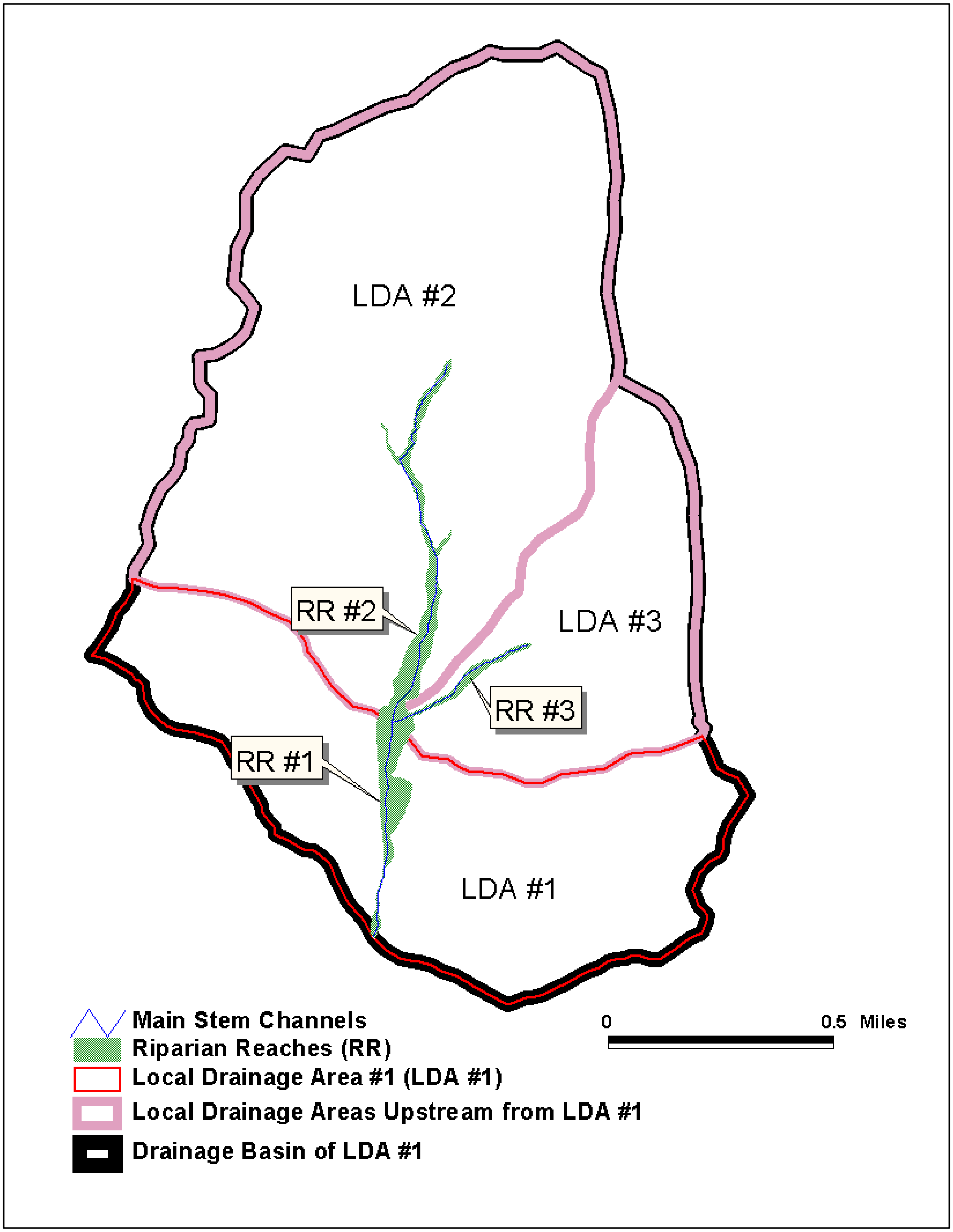

Figure 2. Relationship of riparian reaches, local drainage areas, and drainage basins

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 3). 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), minus the area of the bankfull channel. This is the area above the bankfull channel that is flooded when maximum channel depth is twice the maximum depth at the bankfull stage. The floodprone area usually includes most or all of the point bar deposits below the scarp rising to the lowest distinct terrace.

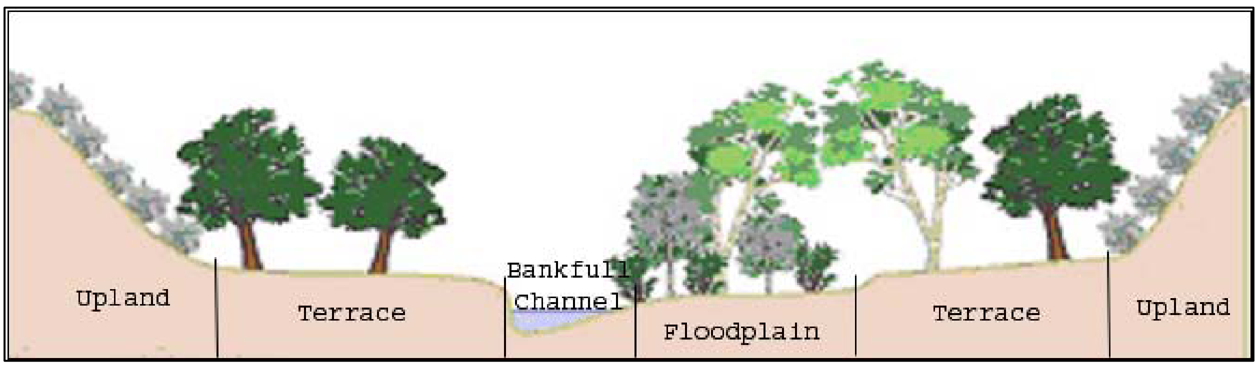

Figure 3. Illustration of riparian ecosystem geomorphic surfaces

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 a linear corridor of variable width along perennial, intermittent, and ephemeral streams. Intact riparian systems exhibit distinctive geomorphic features and vegetation communities that reflect long-term stream processes as well as the ongoing 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 eight geomorphic zones based on our field investigations, topographic maps, the maps and descriptions provided in the county soil survey (Bowman 1973), and the geologic map of the region (Strand 1962). Figure 4 presents a generalized representation of the landscape

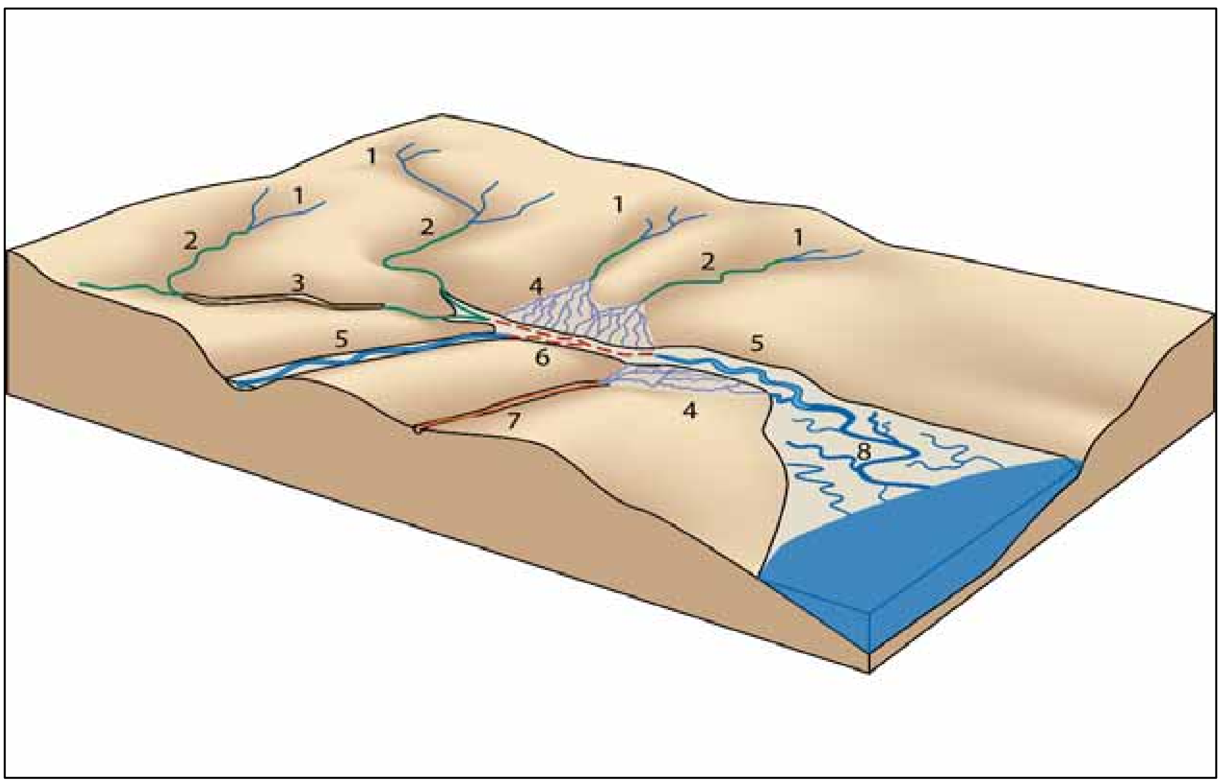

Figure 4. Generalized representation of landscape settings associated with geomorphic zones

position of each geomorphic zone. We assigned each riparian reach to a geomorphic zone using aerial photography, baseline assessment data, and field evaluations (see Section 5.1). The following sections describe the typical condition of each of the seven geomorphic zones in terms of geomorphology and vegetation structure. The accompanying block diagrams and photographs illustrate the usual geomorphic features, landscape setting, and plant communities found in relatively intact examples of each zone. The specific composition of plant communities that occur in each zone varies with elevation, aspect, soils and other factors, as described in publications such as Barbour and Major (1977), Warner and Hendrix (1984), Stephenson and Calcarone (1999), Californian Coastal Conservancy (2001), Miles and Goudey (2003), and Anchor Environmental Group (2004).

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

Stream channels in Geomorphic Zone 1 (Figure 5) are primarily high-gradient systems within the mountains, and first-order streams in the foothills. Soil and geologic mapping (Bowman 1973, Strand 1962) usually indicate 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 coastal sage scrub, extends to the top of the bank. Riparian vegetation has been grazed heavily along many Zone 1 streams, but channel incision is generally minimal due to bedrock control.

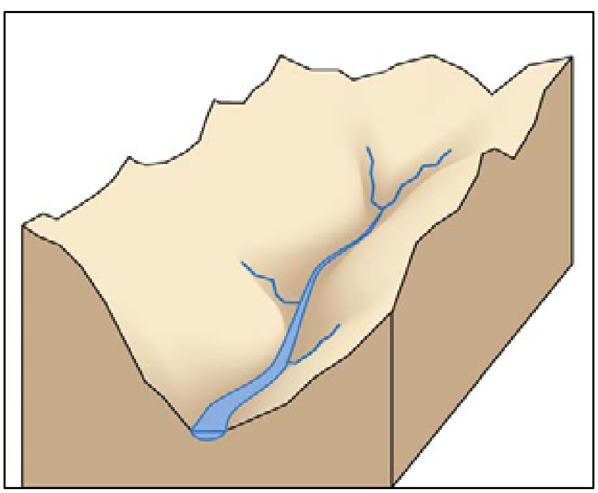

Figure 5. General form of Geomorphic Zone 1 and view of typical reach.

4.2.2 Geomorphic Zone 2: Small floodplains and terrace fragments in mountain and foothill valleys.

Stream channels in Geomorphic Zone 2 (Figure 6) 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 have narrow floodplains, and narrow, discontinuous terraces. Riparian vegetation dominated by sycamore, willows, and mulefat is restricted to the floodplains and terraces, usually forming narrow strips along the channel through fan and colluvial sections. In sheltered locations, the adjacent colluvial slopes and fans may be occupied by oak woodlands, but in most locations the alluvial zone is directly bordered by the predominant upland vegetation type (most commonly coastal sage-scrub or chaparral). 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. However, the boulder-bar terraces are relatively unsorted material, with uneven, hummocky surfaces. The boulder-bars are typically well-drained, and support a mix of riparian and upland plant species.

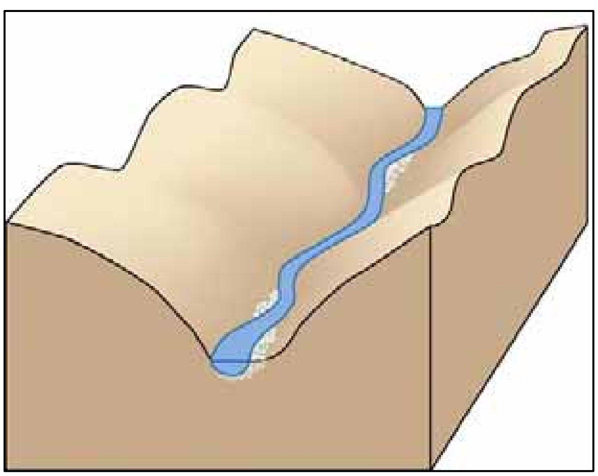


Figure 6. General form of Geomorphic Zone 2 and view of typical reach

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

Geomorphic Zone 3 (Figure 7) 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). These areas usually are mapped as Quaternary Alluvium (Strand 1962).

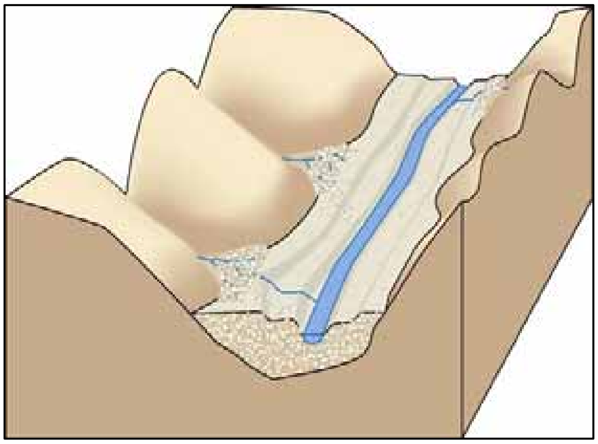

Figure 7. General form of Geomorphic Zone 3 and view of typical reach.

Zone 3 reaches occur at and below the confluence of high-gradient tributary streams with larger channels. The steep tributaries deliver coarse, unsorted materials which are distributed downstream. Usually, the main channel runs across bare cobbles and boulders, while the slightly higher adjacent terraces will have a shallow soil that fills between the rocks and forms a rough, but fairly level surface. Because the terraces consist of very coarse material they typically support upland shrubs. Oaks and sycamores are often present but usually as scattered individuals. Overall, however, continuous riparian communities are restricted to the immediate vicinity of the stream channels. Very few reaches were designated as Geomorphic Zone 3, but where it occurs, it is distinctive.

4.2.4 Geomorphic Zone 4: Steep alluvial fans.

Where tributary streams enter larger valleys in mountainous terrain, fairly steep, truncated alluvial fans occur (Figure 8). These typically consist of coarse material (boulders and cobbles) where the channel exits from the confinement of the tributary valley walls, and they become more fine-textured as the fan descends and widens to merge with the larger valley floor. Channel systems often change form as they traverse a fan, and different patterns are displayed among fans in seemingly similar settings. Often, a distinct, single-thread channel exits the canyon mouth, suddenly takes on a braided pattern as it crosses the coarse materials at the apex of the fan, then re-forms into a single thread channel as it moves across the face of the fan to the

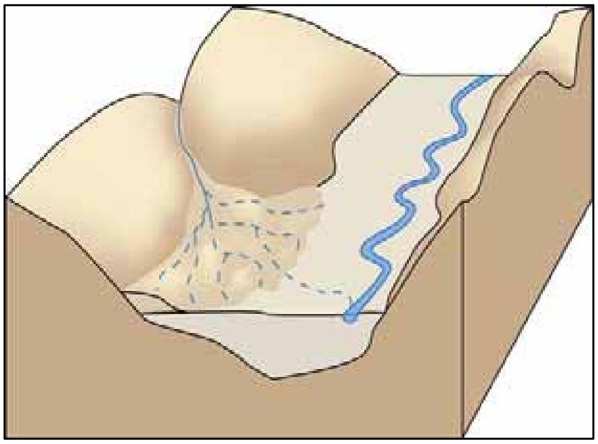

Figure 8. General form of Geomorphic Zone 4 and view of typical reach.

valley floor. These channels all tend to be indistinct, and only storm runoff is carried as surface flows. The majority of the time, the channels are dry, and any water emanating from the tributary valley mouth tends to travel through the fan subsurface. A more stable, well-developed channel typically occurs at the base of the fan where ground water discharges and moves to the main valley floor. Because there is little or no water at or near the surface most of the time, typical riparian species such as oaks, willows, and cottonwood occur only along the channels at the top and bottom of lateral fans. The vegetation along the majority of the channel system across the face of the fan is similar to the surrounding upland community (typically chaparral).

4.2.5 Geomorphic Zone 5: Alluvium of meandering streams in low-gradient valleys.

Geomorphic Zone 5 (Figure 9) is characterized by sinuous channel systems that meander widely across the valley floor, have well-developed floodplains with alternating bars, and have one or more broad terraces that 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 shrub communities.

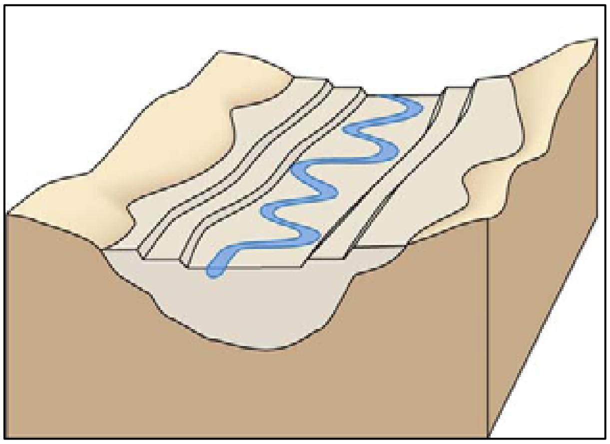

Figure 9. General form of Geomorphic Zone 5 and view of typical reach.

4.2.6 Geomorphic Zone 6: Valley fill

Some reaches of the major stream valleys have been filled with deep, well-drained sediments that show only trace channel systems and little or no terrace development (Figure 10). These areas may slope somewhat toward the valley walls, but do not appear to be created by distinctive lateral fans such as those characteristic of Zone 4. Rather, the valley fill material in Zone 6 has the appearance of having originated higher in the main valley, and was likely deposited in a braided or highly meandering flow environment. As a result, the valley floor is relatively flat, and usually lacks distinctive continuous terraces. In some areas, most flows evidently pass through these reaches subsurface. Where farming or grazing occurs, the channel system may be obliterated completely. However, remnant strips of riparian species (cottonwood, mulefat) suggest that, where subsurface water is available, riparian communities

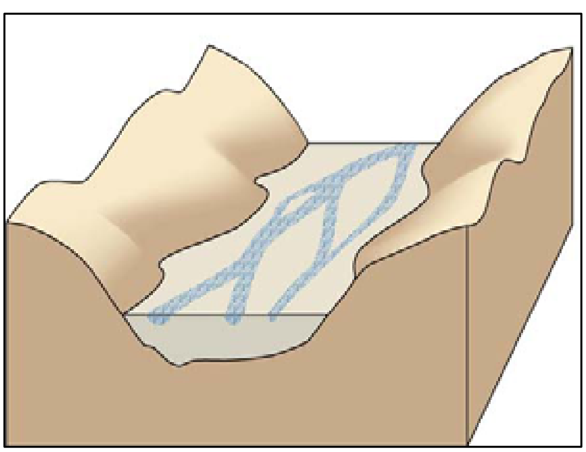

Figure 10. General form of Geomorphic Zone 6 and view of typical reach.

can be established. Re-establishment of a channel system, with particular attention to springs and shallow groundwater areas, may allow restoration of fairly continuous riparian corridors through Zone 6 reaches.

4.2.7 Geomorphic Zone 7: Sandy wash

A distinctive sandy wash channel type occurs in a limited number of small valley settings in the foothills. In the Otay watershed, this type exists only as short segments within reaches designated as predominantly other geomorphic zones. The type consists of a relatively narrow, flat-bottomed channel with low, distinct banks that give way to gently sloping alluvial and/or colluvial deposits (Figure 11). The alluvial deposits flanking the channel do not include any

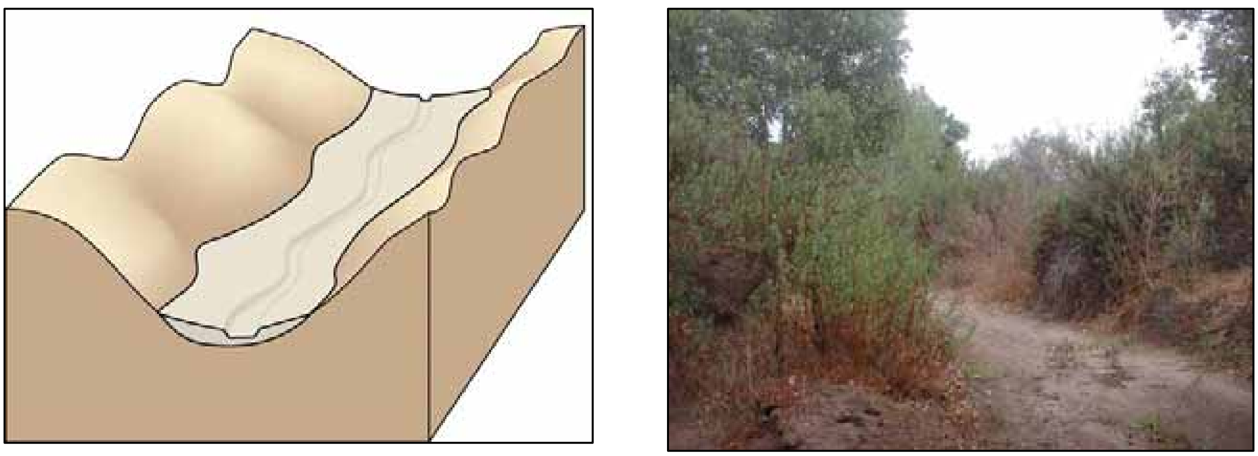

Figure 11. General form of Geomorphic Zone 7 and view of typical reach

significant terrace systems, but instead are occupied by upland vegetation. The form of the valleys where these systems occur suggests that the coarse alluvial deposits are not deep. Riparian vegetation consists mostly of scattered, sparse stands of mulefat within the channel, but occasional isolated oaks, cottonwoods, and sycamores indicate that a relatively continuous riparian corridor might be re-established within Zone 7 reaches through land use changes and light planting. The distinctive channel, with well-established banklines, the sloping deposits flanking the channel, and the apparent frequent (but brief) occurrence of surface flows distinguish this Zone from the valley fill type (Zone 6), where identification of shallow groundwater areas is a more critical restoration factor.

4.2.8 Geomorphic Zone 8: Tidal reaches

Below Interstate 5, the lower Otay River passes through an intertidal zone before discharging to San Diego Bay. The stream and associated wetlands in this zone have been highly modified by fill and channelization, and much of the area has been converted to salt evaporation ponds. Only small remnants of the native marsh system remain (Figure 12). The natural form of the channel system is entirely modified; the channel form and pattern illustrated in Figure 12 is based on more intact systems in similar settings in the region. While restoration of this reach will clearly require channel re-alignment and reconfiguration in addition to fill removal, no specific restoration template is offered in this document. If restoration opportunities occur, the specific design will depend on the land available, and a detailed analysis of the potential to re-establish the mainstem channel as well as tidal channels within the space available.

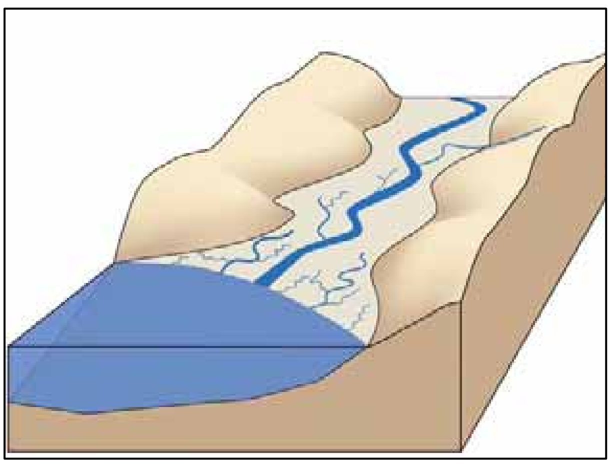

Figure 12. General form of Geomorphic Zone 8 and view of typical reach.

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 13) 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

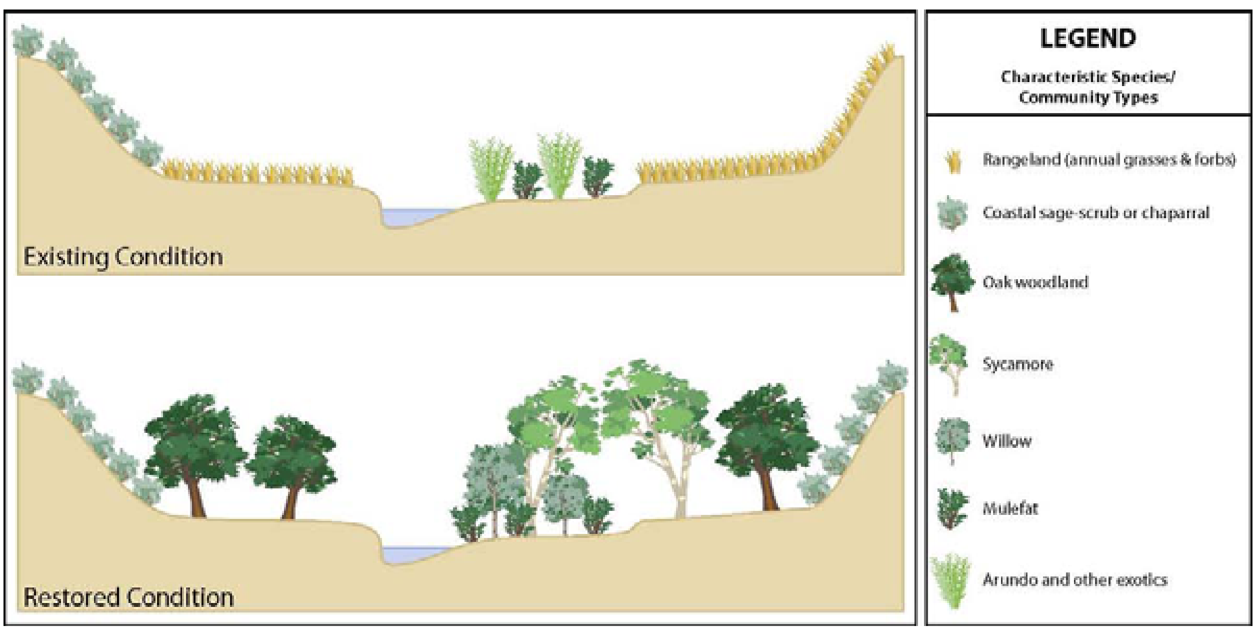

Figure 13. Typical pre- and post-restoration conditions of the Natural Template

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. In the Otay basin, channel incision, groundwater withdrawal, and surface water storage and diversion may preclude application of the Natural Template in many areas. However, most reaches in Geomorphic Zone 1, and a large 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 13. 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 14) 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 reaches assigned to the Incised Template are in Geomorphic Zones 2 or 5. Figure 14 illustrates a typical Zone 5 incised condition, and the proposed restoration approach, which includes reconfiguration of surfaces, removal of exotic vegetation, and extensive native plantings.

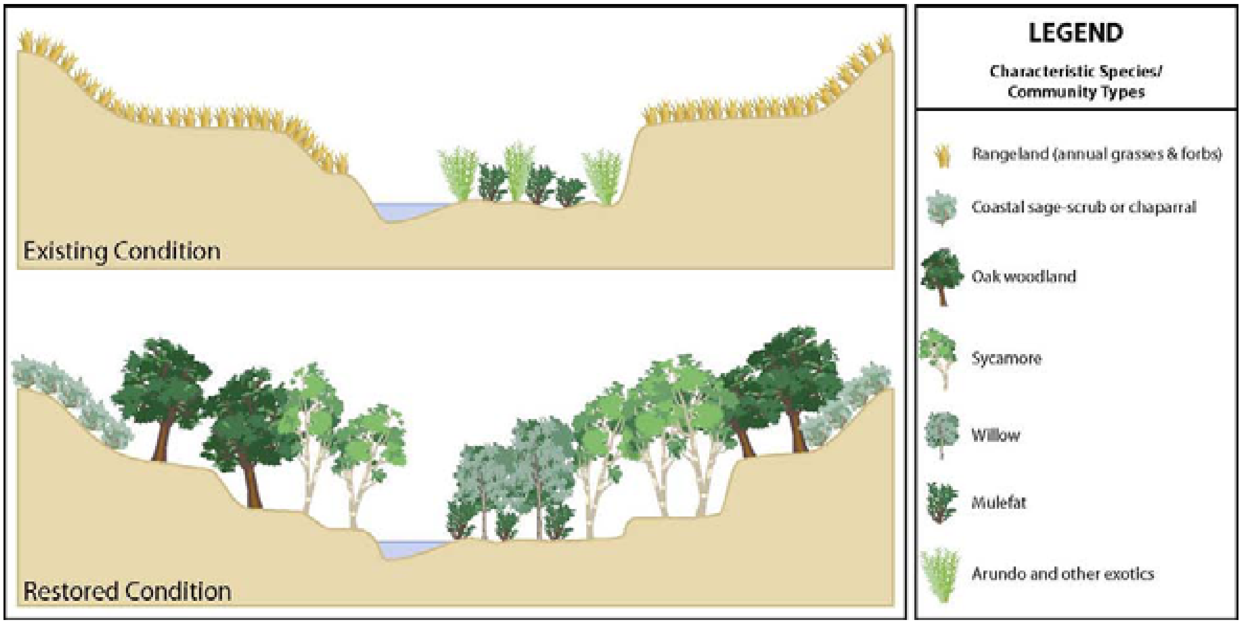

Figure 14. Typical pre- and post-restoration conditions of the Incised Template

4.3.3 Constrained Channel Template

The Constrained Template (Figure 15) 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 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, making successful restoration efforts more uncertain, as compared with less constrained systems. The Constrained Template was assigned primarily to Zone 2 and 5 stream reaches. Figure 15 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.

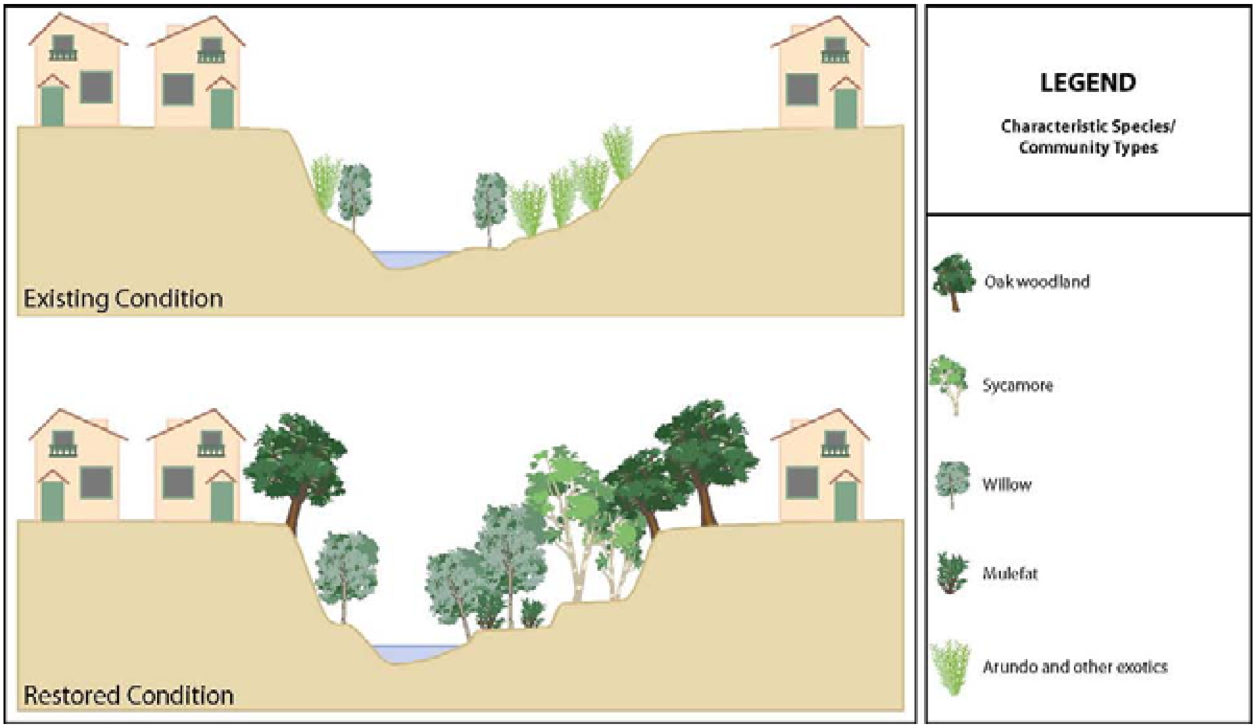

Figure 15. Typical pre- and post-restoration conditions of the Constrained Template

4.3.4 Aggraded Channel Template

Numerous stream reaches within the study area show signs of having received excess sediment in historic times, but in most cases these areas have adjusted by changing channels size and configuration, which is accounted for in the other templates described above. The Aggraded Template is applied only to stream reaches that are affected by large amounts of recent sedimentation such that there is no distinct organization of surfaces. In the Otay basin, this situation is limited to relatively few sites. 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 16.

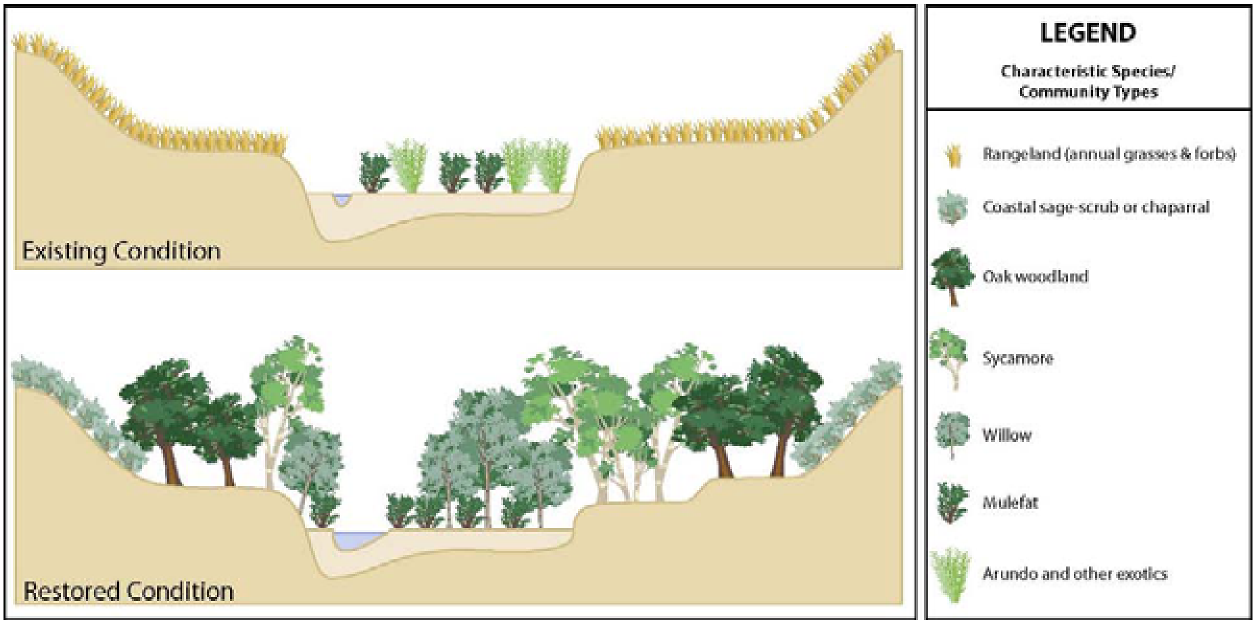

Figure 16. Typical pre- and post-restoration conditions of the Aggraded Template

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 17). Through minimal restoration of native vegetation, this template may provide some, albeit limited, increase in 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 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 2 and 5.

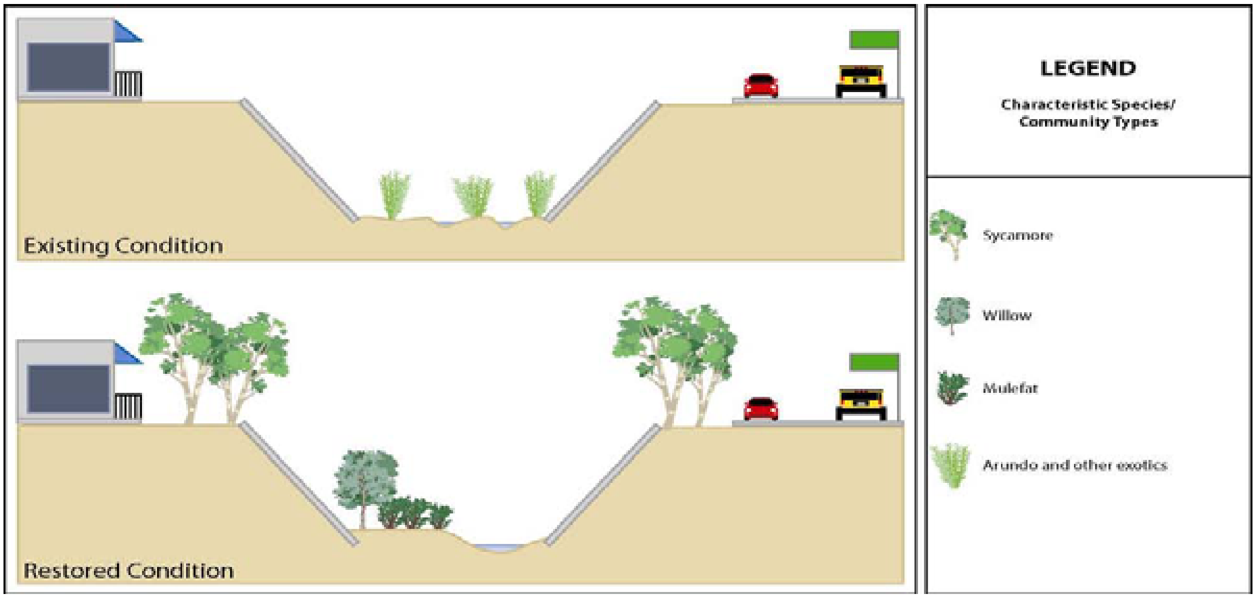

Figure 17. Typical pre- and post-restoration conditions of riparian reaches assigned to the Engineered Template

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 Moderate 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. Sites requiring the removal of concrete, rip-rap, or asphalt bank protection also are included in this category. Heavy equipment such as bulldozers, graders, track-hoes will be required. 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 Simulation of Restoration Scenarios

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 in the watershed, given a specific set of criteria or objectives. To this end we simulated three of many possible restoration scenarios. In the first scenario, 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.

Three restoration scenarios were simulated to illustrate a few of the many possible ways to utilize the information developed during this project. In the first restoration scenario, 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 scenario assumed an infinite level of resources available for restoration, and that wherever restoration will increase integrity indices, it will be accomplished.

In order to simulate the first restoration scenario a GIS theme with attributes representing Geomorphic Zone, Restoration Template, and Level of Effort was developed for each riparian reach in the study area in order to calculate post-restoration indices for each riparian reach. 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. Seven of the original 27 indicators include in the hydrology, water quality and habitat integrity indices represent riparian reach scale factors. These seven indicators were assigned new scores of 1 to 5, where 5 represented conditions of a fully functional riparian reach (Table 1). Most of the local drainage and drainage basing indicators are not affected by the application of a Restoration Template, since they 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) do 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).

Unlike the first scenario, which focused solely on restoration within the riparian ecosystem proper (i.e., stream channel geomorphic features, riparian vegetation, etc.), the second and third scenarios consider the effects of conducting restoration in the upland areas (i.e., the local drainage area and the drainage basins of the riparian reaches). The objective of these scenarios was to show how restoration of uplands could increase riparian reach integrity. Specifically, in the Restoration Scenario 2, areas of active or former rangeland land use were restored to native vegetation, and in Restoration Scenario 3, areas of active or former rangeland land use and agriculture were restored to native vegetation.

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

Restoration Template	Indicators								
	AHC_{RR}*	AHC_{DB}	FI_{RR}	SR_{RR}	EXO_{RR}	RCC_{RR}	RCC_{DB}	VC_{FLOOD}	$VC_{TERRACE}$
Natural (1)	5	Cumulative	5	5	5	5	Cumulative	5	5
Incised (2)	5	Cumulative	5	4	5	5	Cumulative	4	4
Constrained (3)	NC**	Cumulative	NC	2	5	5	Cumulative	3	3
Aggraded (4)	NC	Cumulative	NC	NC	5	5	Cumulative	5	5
Engineered (5)	NC	Cumulative	NC	1	5	5	Cumulative	1	1
Impractical (6)	NC	Cumulative	NC	NC	NC	NC	Cumulative	NC	NC

* AHC_{RR} = Altered Hydraulic Conveyance – Riparian Reach Scale, AHC_{DB} = Altered Hydraulic Conveyance – Drainage Basin Scale, FI_{RR} = Floodplain Interaction – Riparian Reach Scale, SR_{RR} = Sediment Regime Index – Riparian Reach Scale, EXO_{RR} = Exotic Plant Species Index - Riparian Reach Scale, RCC_{RR} = Riparian Corridor Continuity – Riparian Reach Scale, RCC_{DB} = Riparian Corridor Continuity – Drainage Basin Scale, VC_{FLOOD} = Vegetation Condition Index – Floodplain, $VC_{TERRACE}$ = Vegetation Condition Index – Terrace
** NC = No change

5.0 Results and Discussion

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

Figure 18 shows Geomorphic Zones, Figure 19 shows the Restoration Templates, and Figure 20 shows the Level of Effort category assigned to riparian reaches within the study area.

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. 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. However, in the course of conducting field studies the dimensions of geomorphic surfaces throughout the watershed were recorded across a range of geomorphic zones and levels of disturbance. Table 2 presents ranges and average values for channel, floodplain, and terrace dimensions in each geomorphic zone (except the tidal Zone 8), as determined from field measurements in a sample of the least-disturbed reaches remaining in the study area or region. 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. For example, Zones 3, 5, and 6 normally have one or more terraces present, while Zones 1, 2, 4, and 7 do not. Similarly, in Zone 3 only a single low terrace usually is present, while Zone 5 typically include multiple high, wide terraces. Note that some zones have features which span a particularly wide range of values (e.g. Zones 5 and 6). This generally indicates that the Zone the Zone was encountered in a wide range of valley sizes, and the smaller end of the range of reported values applies to the smallest valleys. The values in Table 2 are not intended to be used

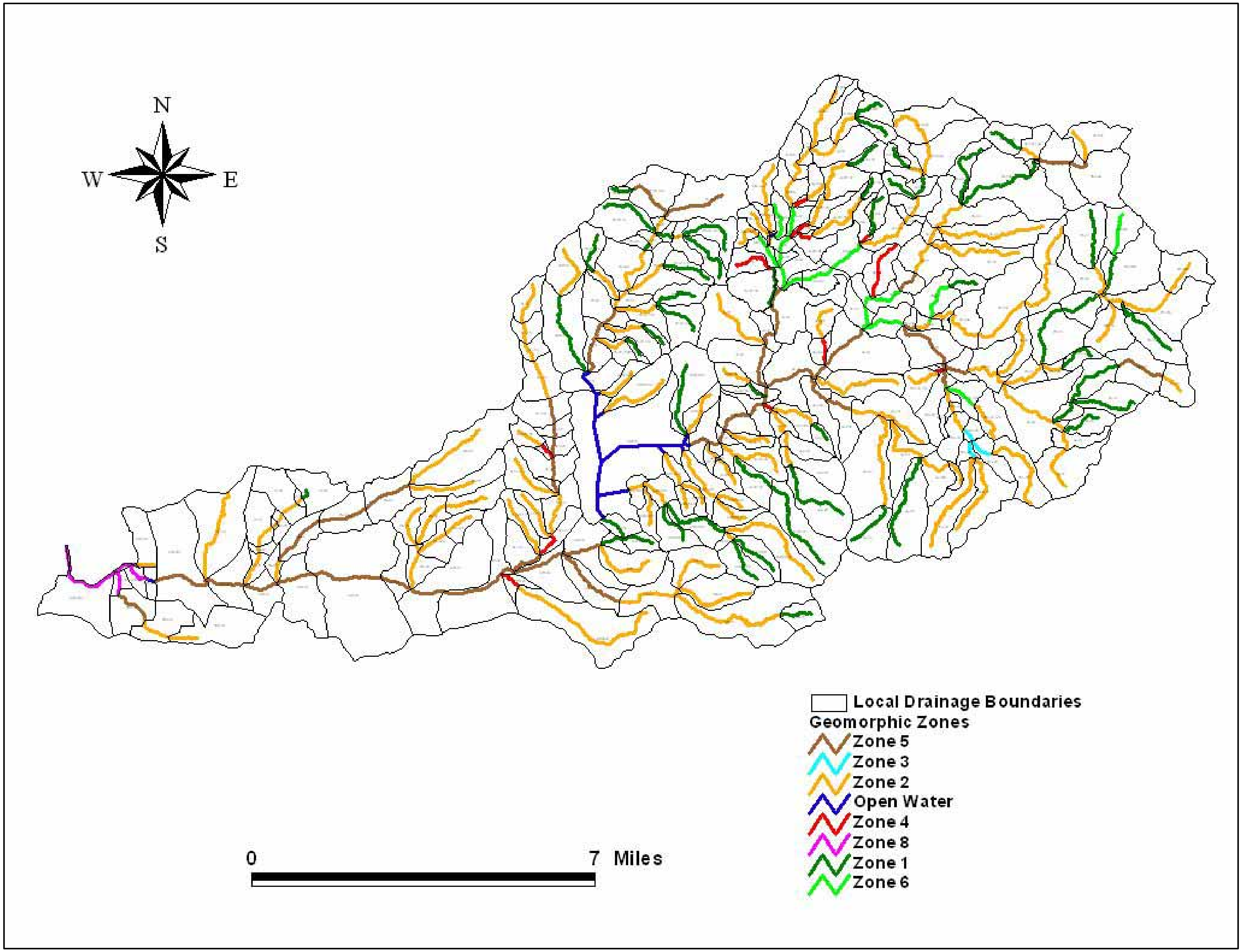

Figure 18. Geomorphic Zone assignments for riparian reaches

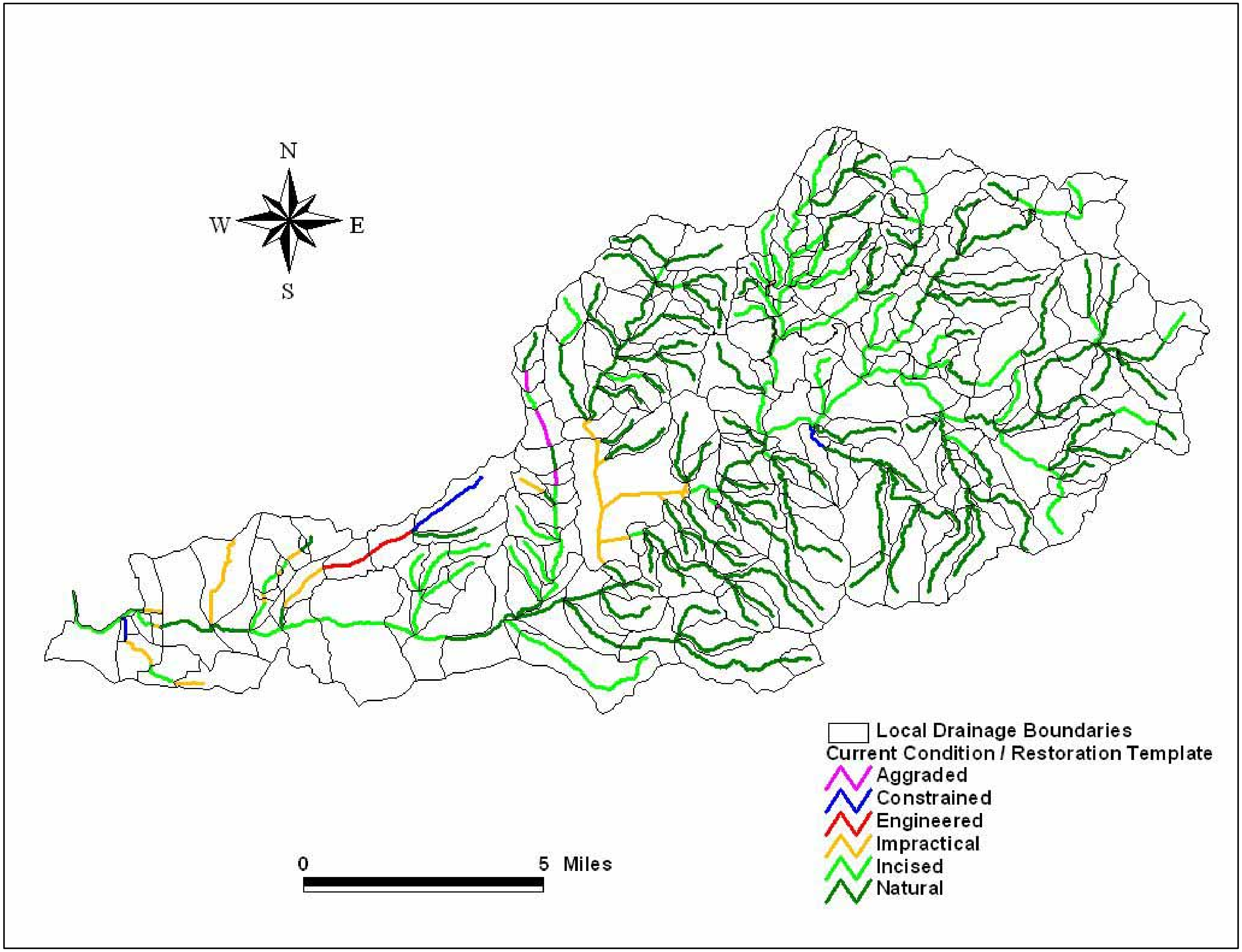

Figure 19. Restoration Template assignments for riparian reaches

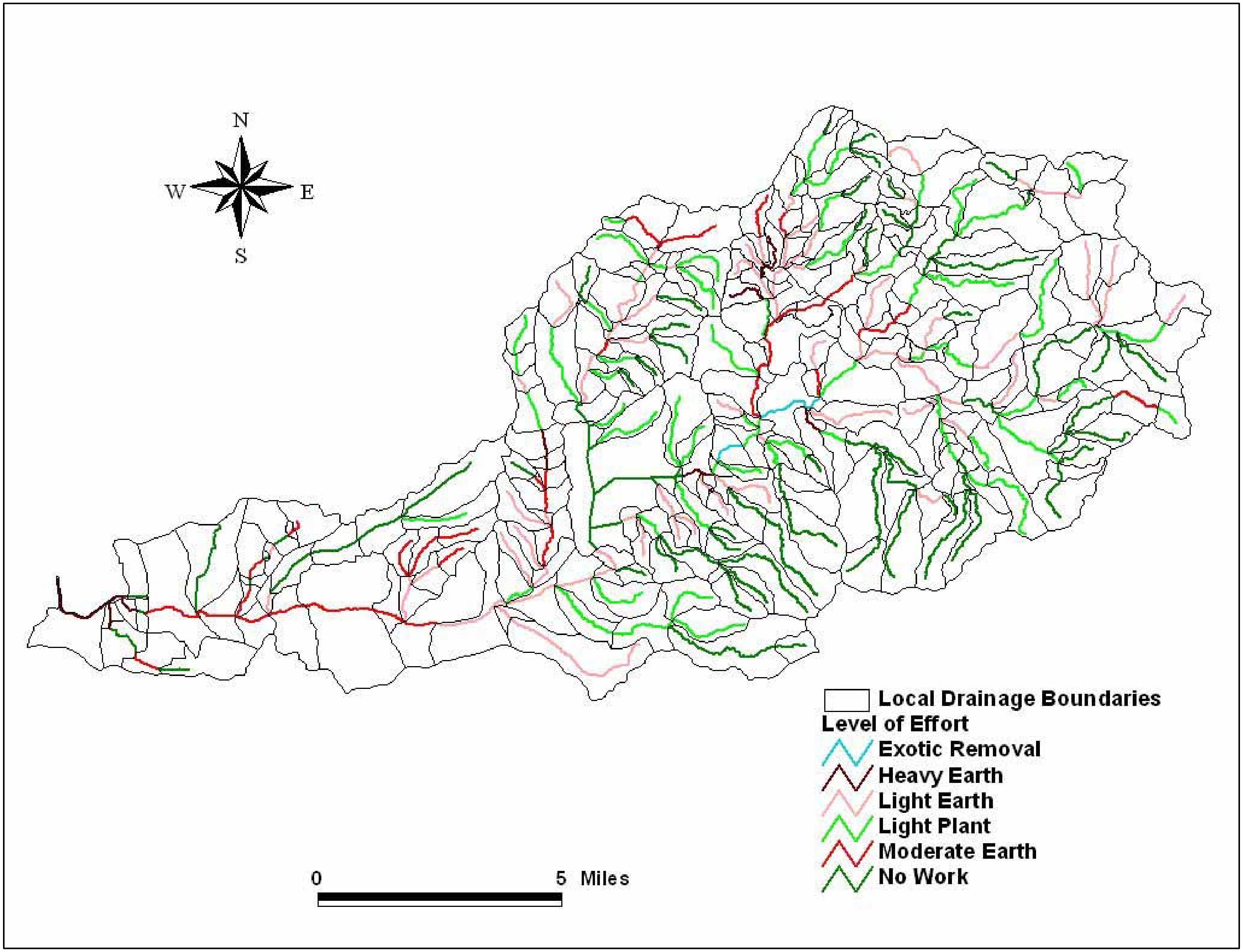

Figure 20. Level-of-Effort assignments for riparian reaches

Table 2. Range and average dimensions of alluvial features by geomorphic zone

Feature	Dimensions	Geomorphic Zone						
		1	2	3	4	5	6	7[A]
Bankfull Width (ft)	Range	3-4	4-6	7.5-8	4-5	6-16	3-20	4-7
	Average	3.5	5	7.6	4.5	11.5	8.4	5.5
Bankfull Max Depth (in)	Range	6-10	8	5-11	3.5-5	6-24	3-12	3-4
	Average	8	8	8.3	4.25	13.2	5.8	3.5
Bankfull Mean Depth (in)	Range	4-8	6-8	4-7	2.5-4.5	3-20	2-11	1-3
	Average	6	7	6	3.5	10	4.6	2
Floodplain Width (ft)	Range	5-14	2-3	12-14.5	7.5-9	4-20	5-21	1-7
	Average	9.5	2.5	13	8.25	14.9	10.2	4
Terrace 1 Width (ft)	Range	NA[B]	NA	10-30	NA	7-120	5-20	NA
	Average	NA	NA	20	NA	70	10.5	NA
Terrace 1 Ht. Above Bankfull (ft)	Range	NA	NA	1.5-2	NA	1-8	1.5-4	NA
	Average	NA	NA	1.75	NA	3.2	2.5	NA
Terrace 2 Width (ft)	Range	NA	NA	NA	NA	35-500	10-150	NA
	Average	NA	NA	NA	NA	160	90	NA
Terrace 2 Ht. Above Bankfull (ft)	Range	NA	NA	NA	NA	3-8	4-15	NA
	Average	NA	NA	NA	NA	5.7	11	NA
Terrace 3 Width (ft)	Range	NA	NA	NA	NA	300-600	NA	NA
	Average	NA	NA	NA	NA	450	NA	NA
Terrace 3 Ht. Above Bankfull (ft)	Range	NA	NA	NA	NA	5-7	NA	NA
	Average	NA	NA	NA	NA	6	NA	NA

[A] No intact examples of Zone 7 were encountered in the Otay watershed, but parts of some Zone 6 reaches might be appropriate for restoration as Zone 7. Dimensions for Zone 7 features presented here are from the San Jacinto watershed. No dimensions are presented for Zone 8 features because no intact examples were encountered in any of the watershed sampled in the region. Restoration of Zone 8 should be based on other published information on tidal creeks.
[B] Not Applicable (e.g., terraces not present)

as strict restoration specifications. Rather, Table 2 and the general descriptions and illustrations of each Zone provided in Section 4.2 should be used to estimate the physical and biological complexity that is appropriate to a particular riparian setting.

5.3 Simulation of Restoration Scenarios

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 in the watershed, given a specific set of criteria or objectives. To this end we simulated three of many possible restoration scenarios. To provide a point of reference for the results of the restoration scenarios simulations, Figures 21, 22, and 23 shows the baseline, normalized hydrologic, water quality, and habitat integrity indices for riparian reaches. The integrity indices, or change in integrity indices, shown in Figures 21-32 is represented 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

In the first scenario, remember that 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 Restoration Scenario 1 are shown as the change in the normalized hydrologic (Figure 24), water quality (Figure 25), and habitat (Figure 26) integrity indices after applying the recommended restoration template. These results show which riparian reaches exhibit the greatest increase in integrity indices without regard to level of effort required to implement the restoration template.

Unlike Restoration Scenario 1, which focused solely on restoration within the riparian ecosystem proper (i.e., stream channel geomorphic features, riparian vegetation, etc.), Restoration Scenarios 2 and 3 simulated the effect on riparian reach integrity by restoring upland areas to native vegetation. Under Restoration Scenario 2, the areas currently in rangeland were simulated as native vegetation communities. Results from Restoration Scenario 2 are shown as the change in normalized hydrologic (Figure 27), water quality (Figure 28), and habitat (Figure 29) integrity indices. Under Restoration Scenario 3, the areas currently in rangeland and agriculture were simulated as native vegetation communities. Results from Restoration Scenario 3 are shown as the change in the normalized hydrologic (Figure 30), water quality (Figure 31), and habitat (Figure 32) integrity indices. These results indicate which riparian reaches exhibit the greatest increase in integrity indices based on restoring upland areas to native vegetation.

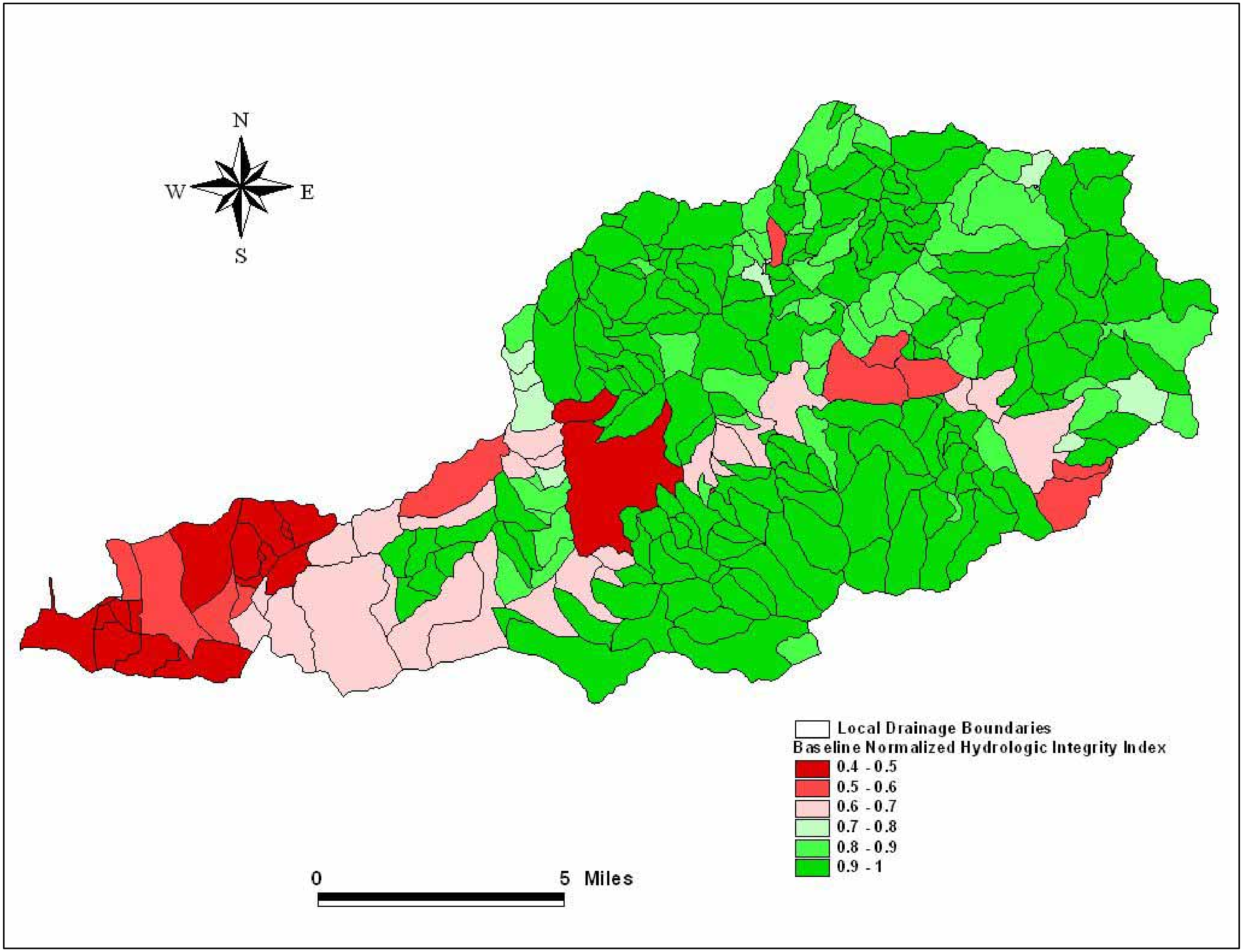

Figure 21. Normalized baseline hydrology integrity indices for riparian reaches

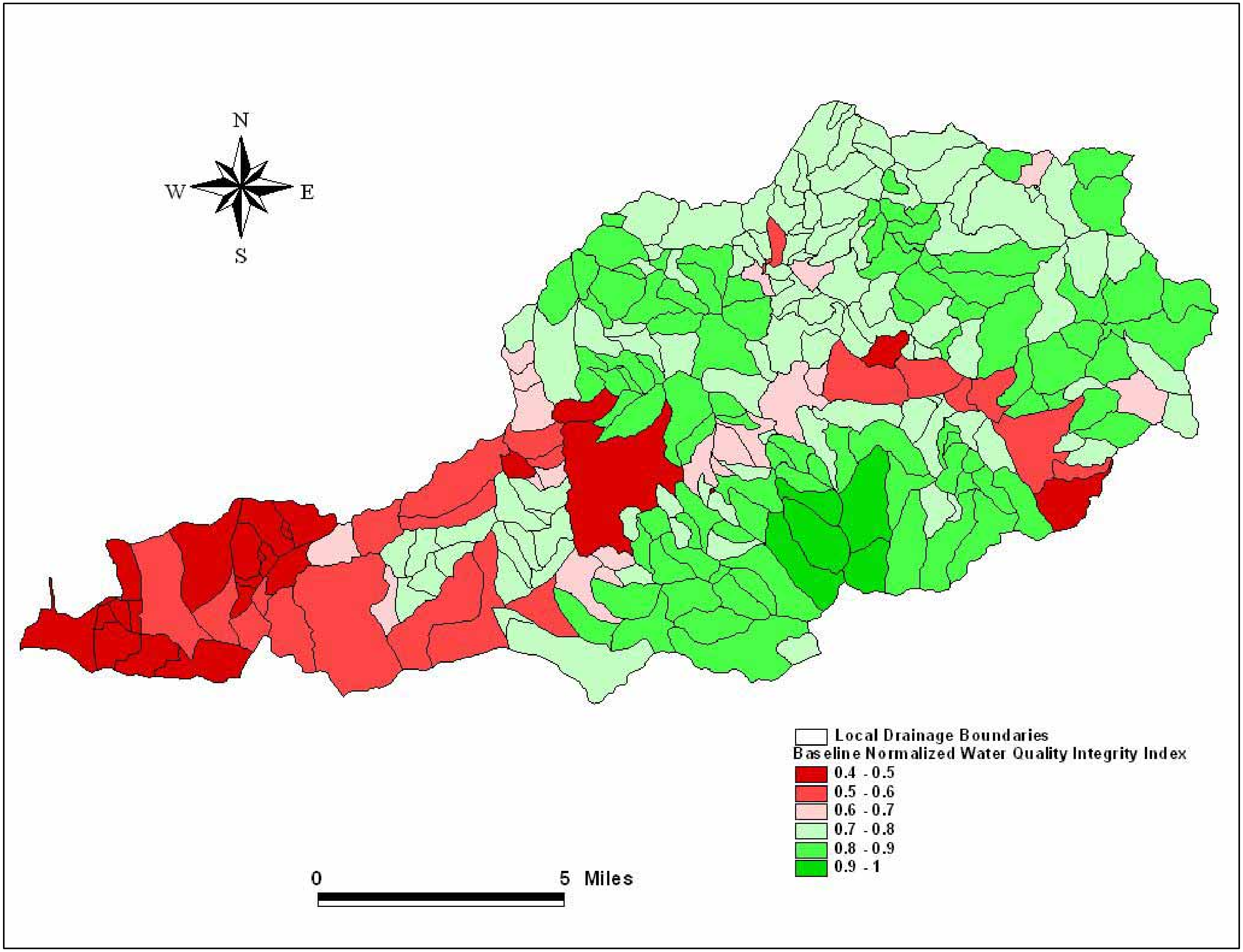

Figure 22. Normalized baseline water quality integrity indices for riparian reaches

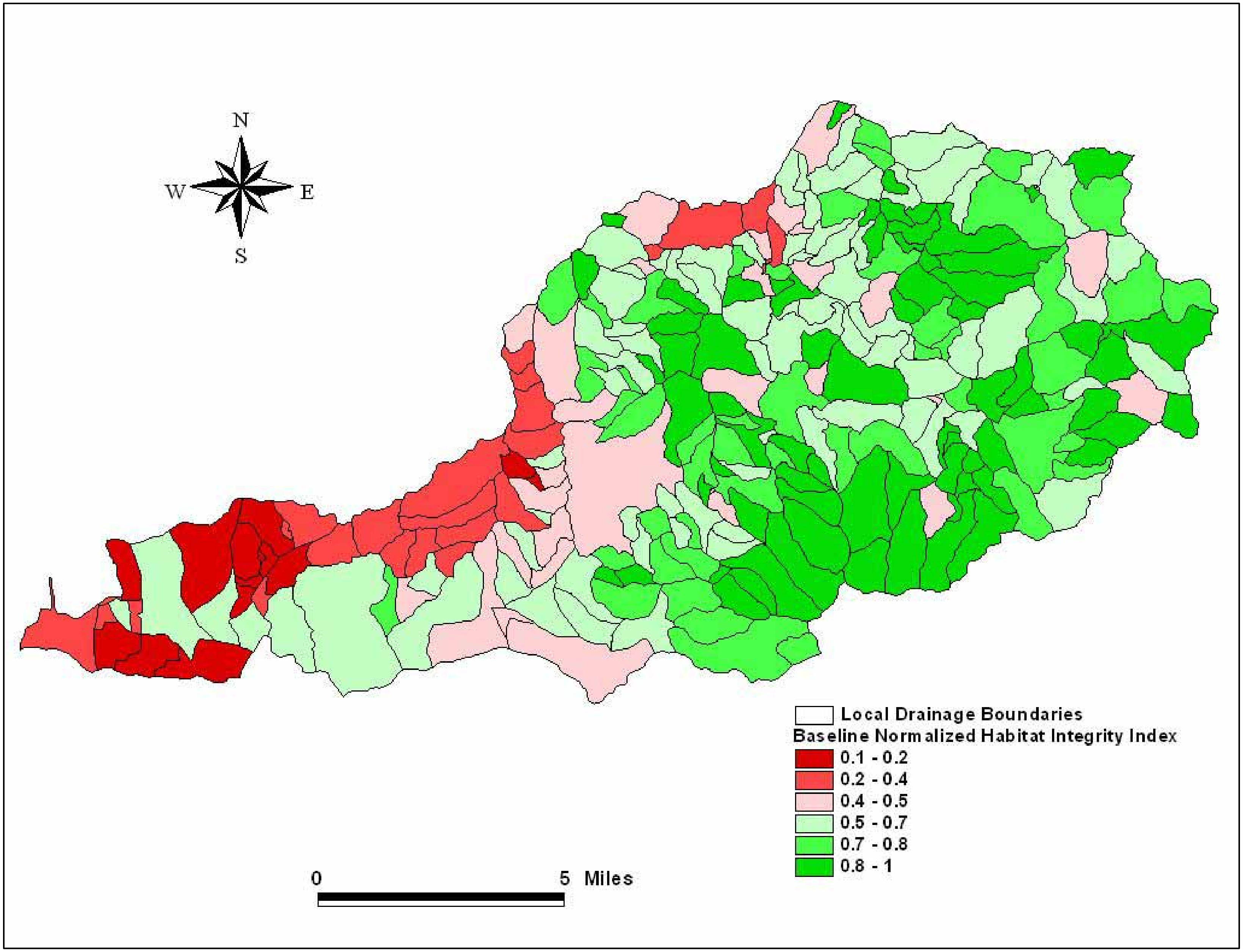

Figure 23. Normalized baseline habitat integrity indices for riparian reaches

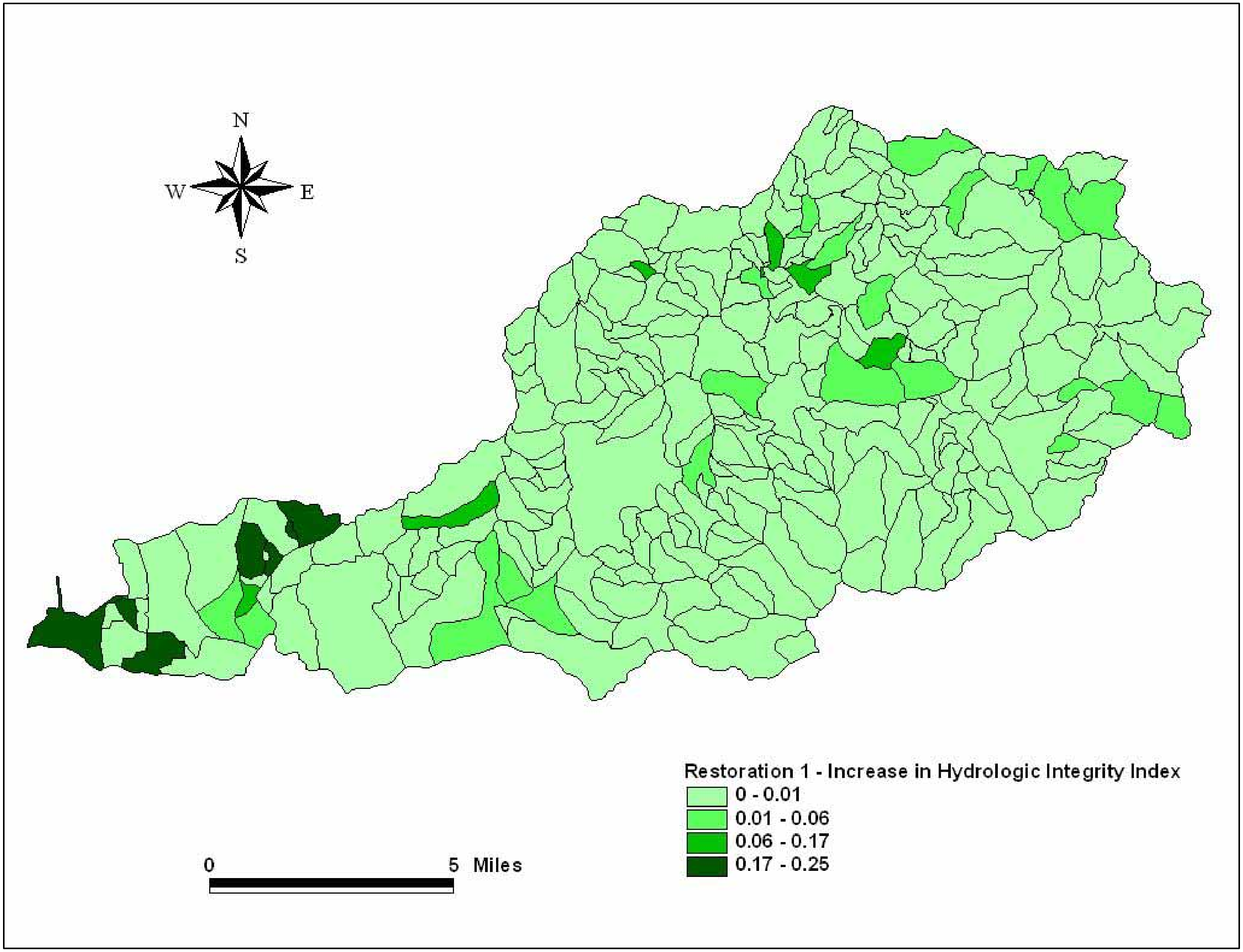

Figure 24. Increase in normalized hydrologic integrity index under Restoration Scenario 1

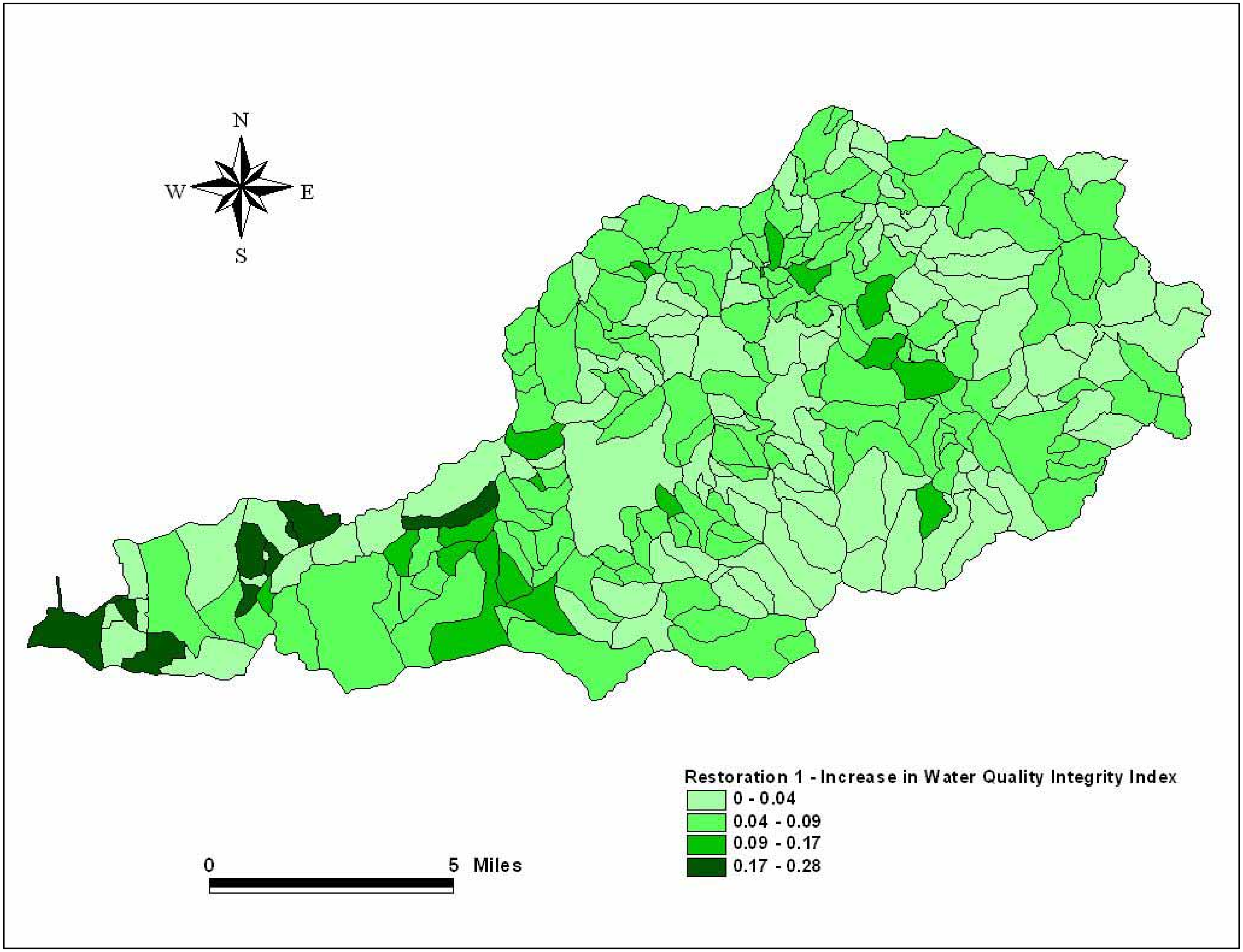

Figure 25. Increase in normalized water quality integrity index under Restoration Scenario 1

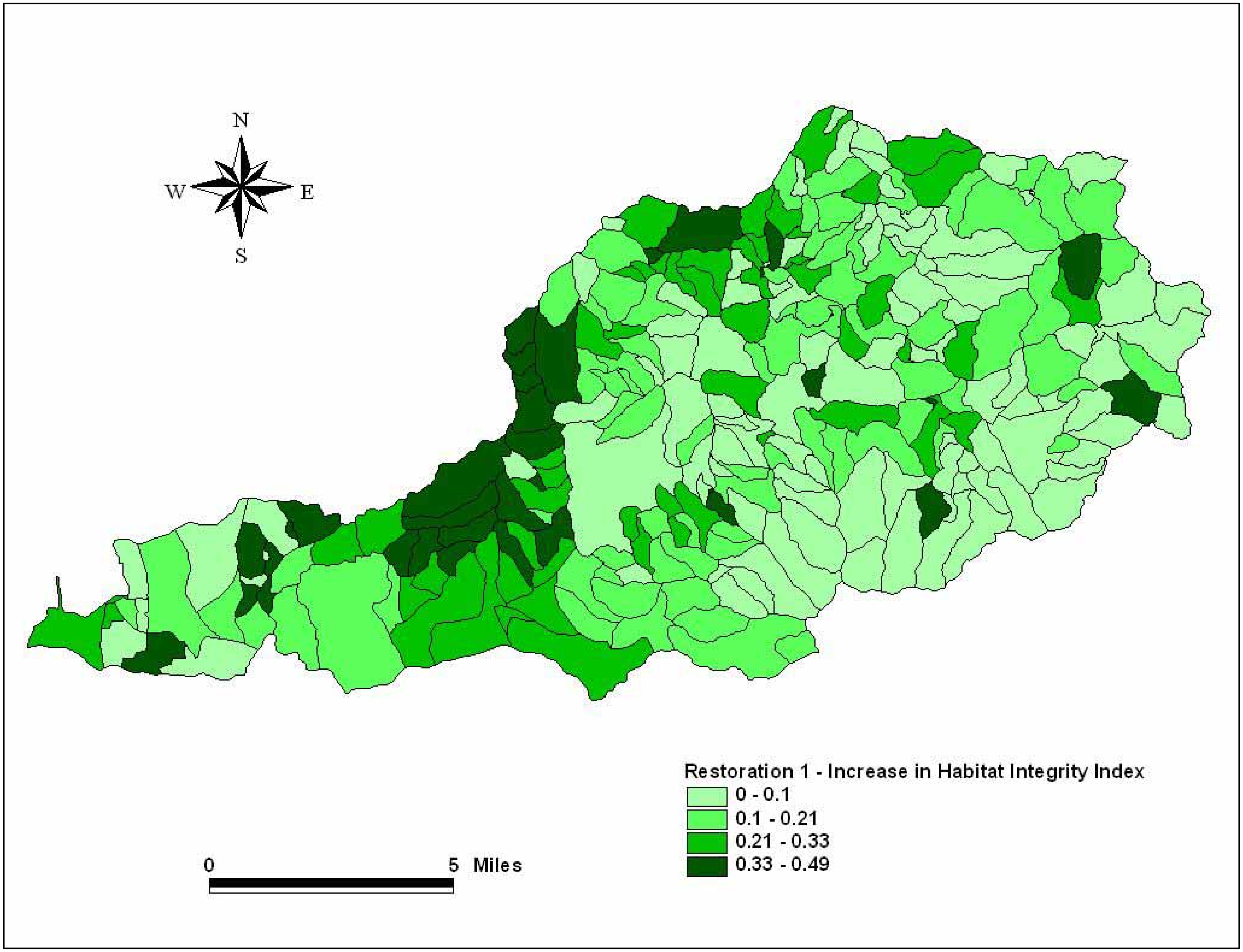

Figure 26. Increase in normalized habitat integrity index under Restoration Scenario 1

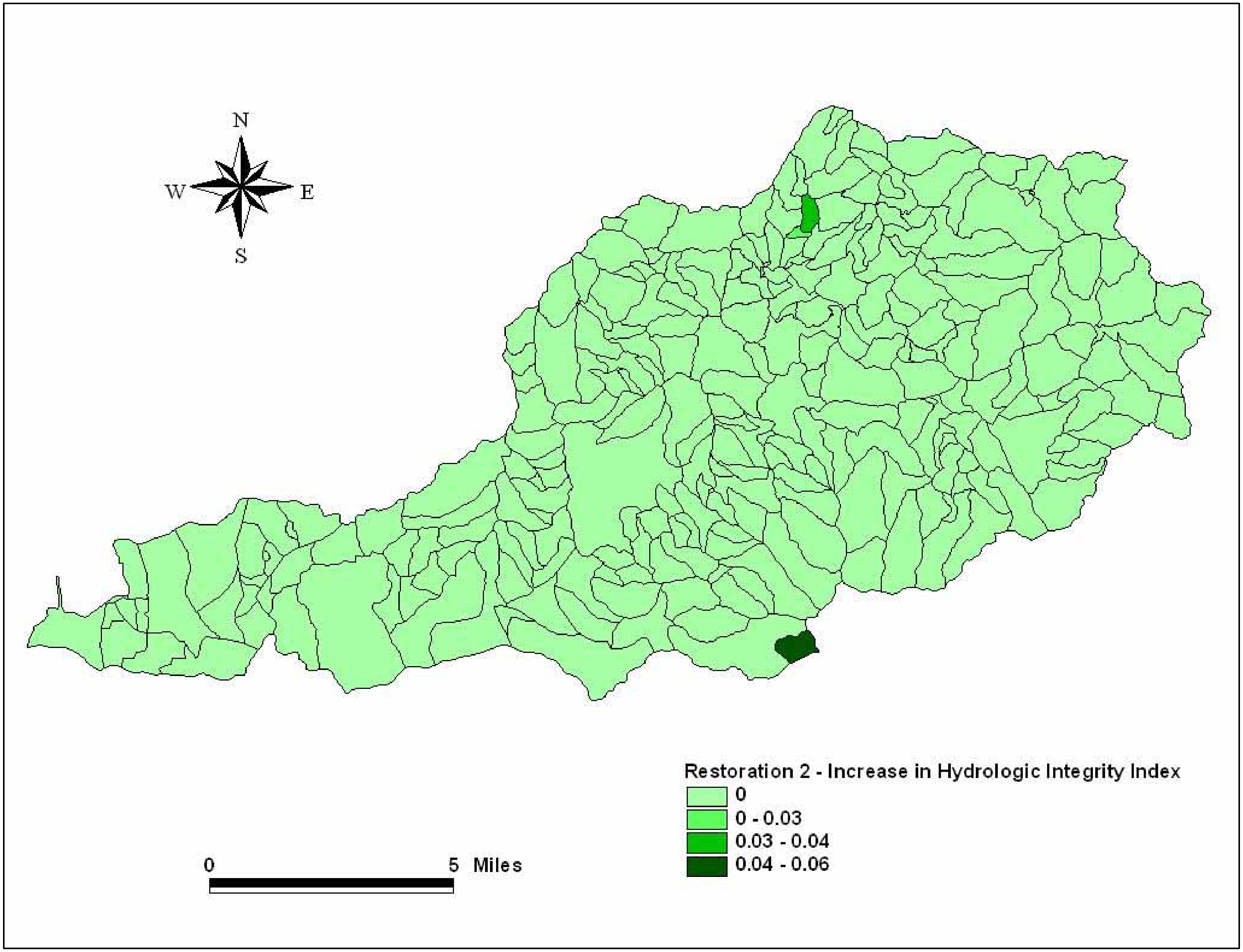

Figure 27. Increase in normalized hydrology integrity index under Restoration Scenario 2

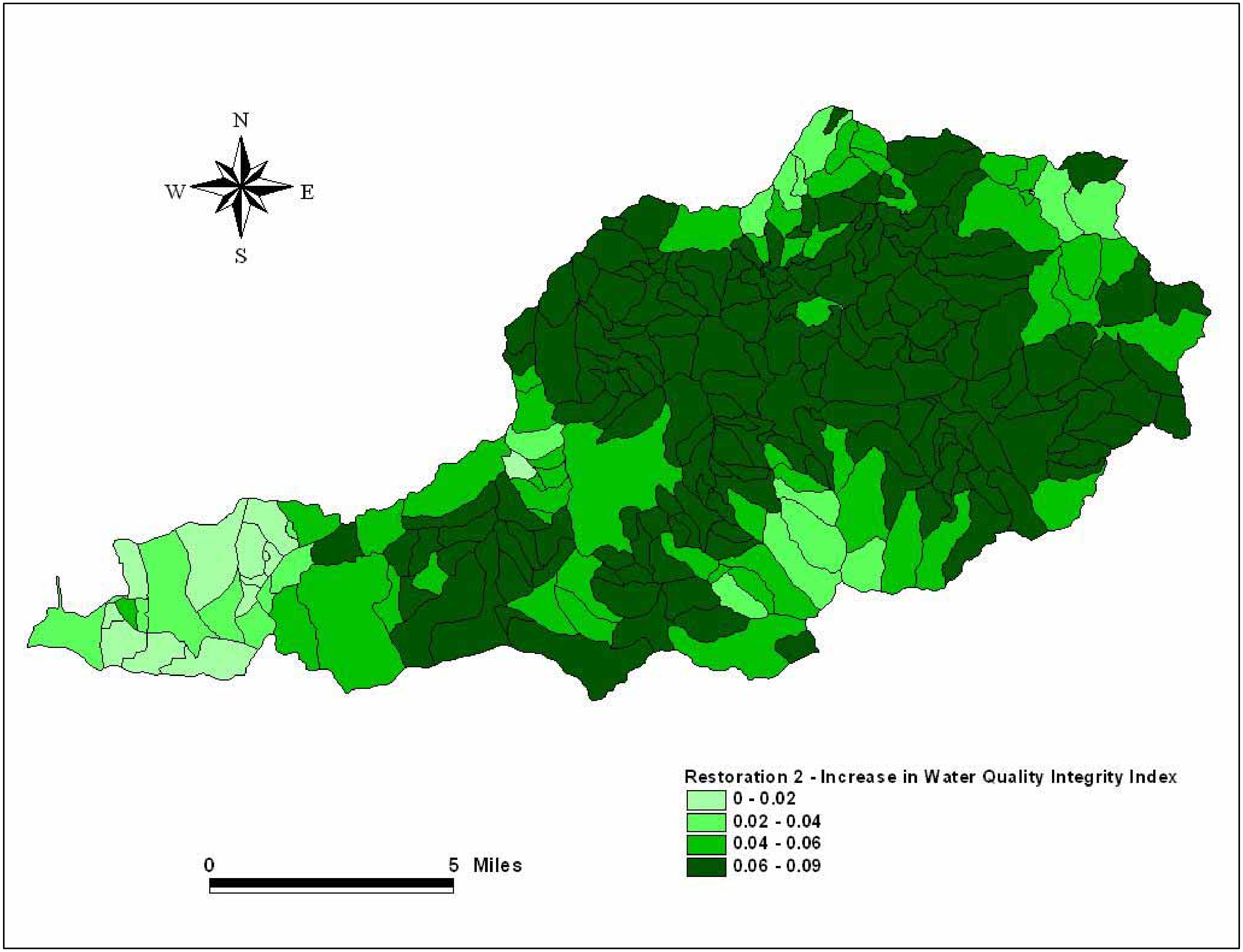

Figure 28. Increase in normalized water quality integrity index under Restoration Scenario 2

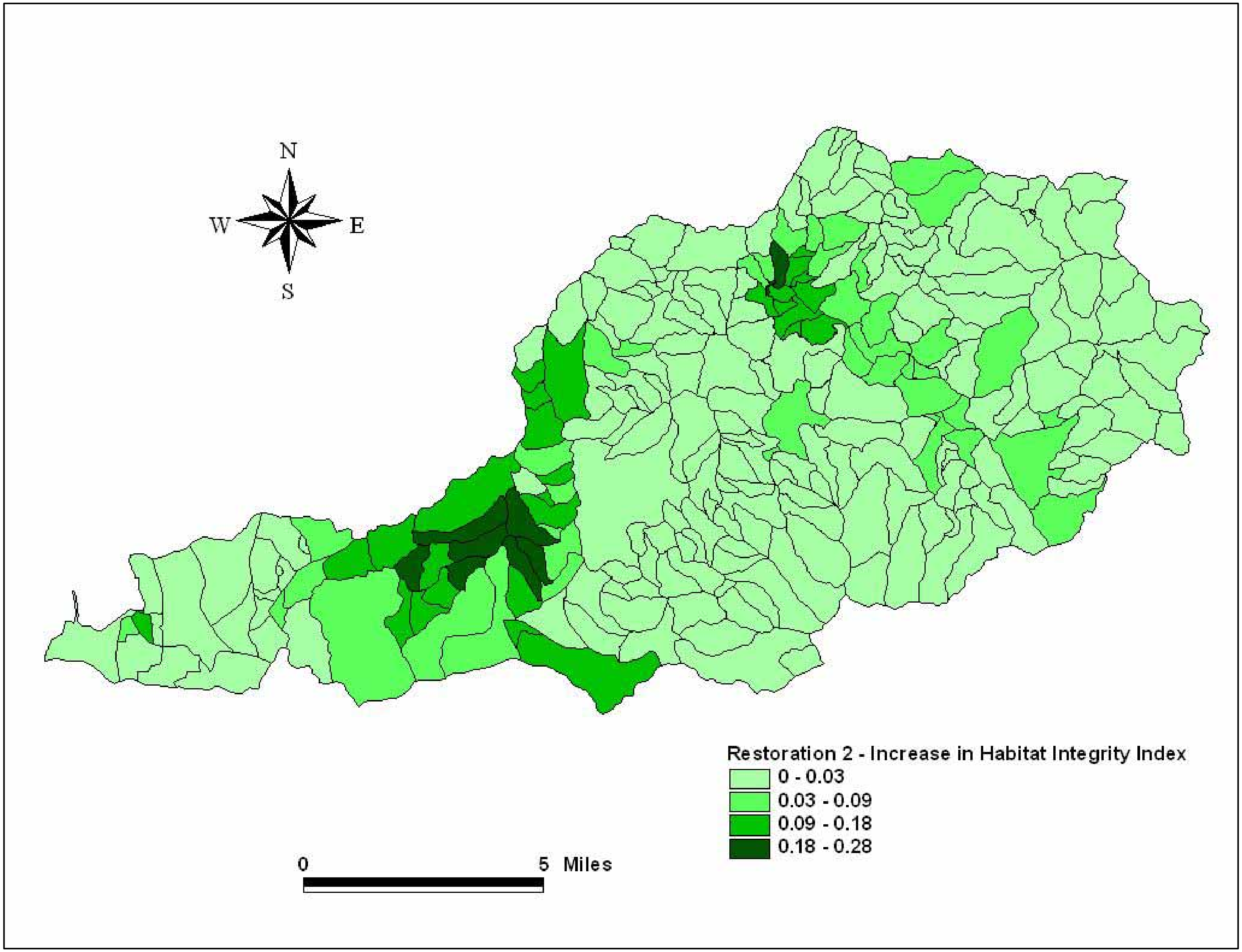

Figure 29. Increase in normalized habitat integrity index under Restoration Scenario 2

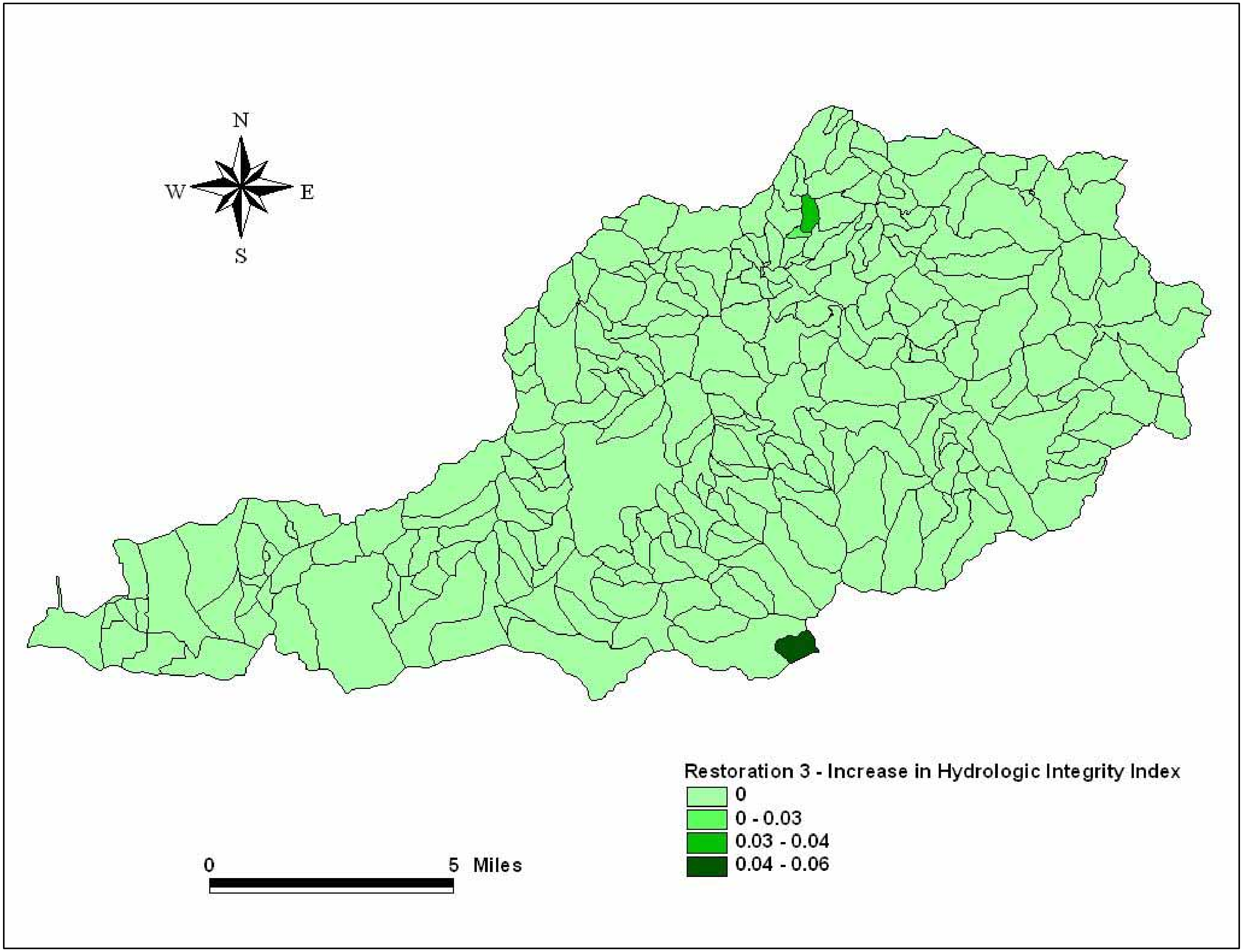

Figure 30. Increase in normalized hydrologic integrity index under Restoration Scenario 3

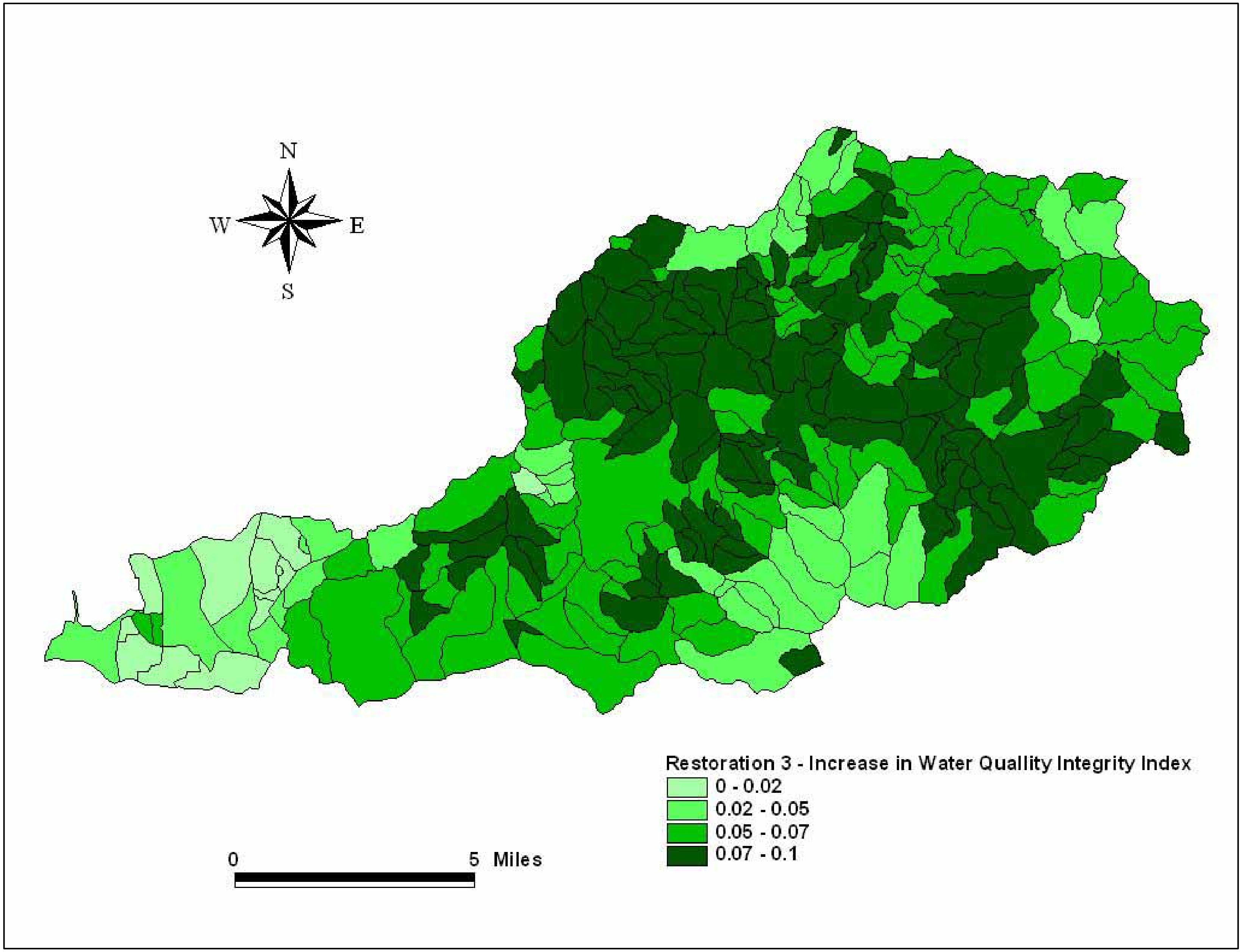

Figure 31. Increase in normalized water quality integrity index under Restoration Scenario 3 simulation

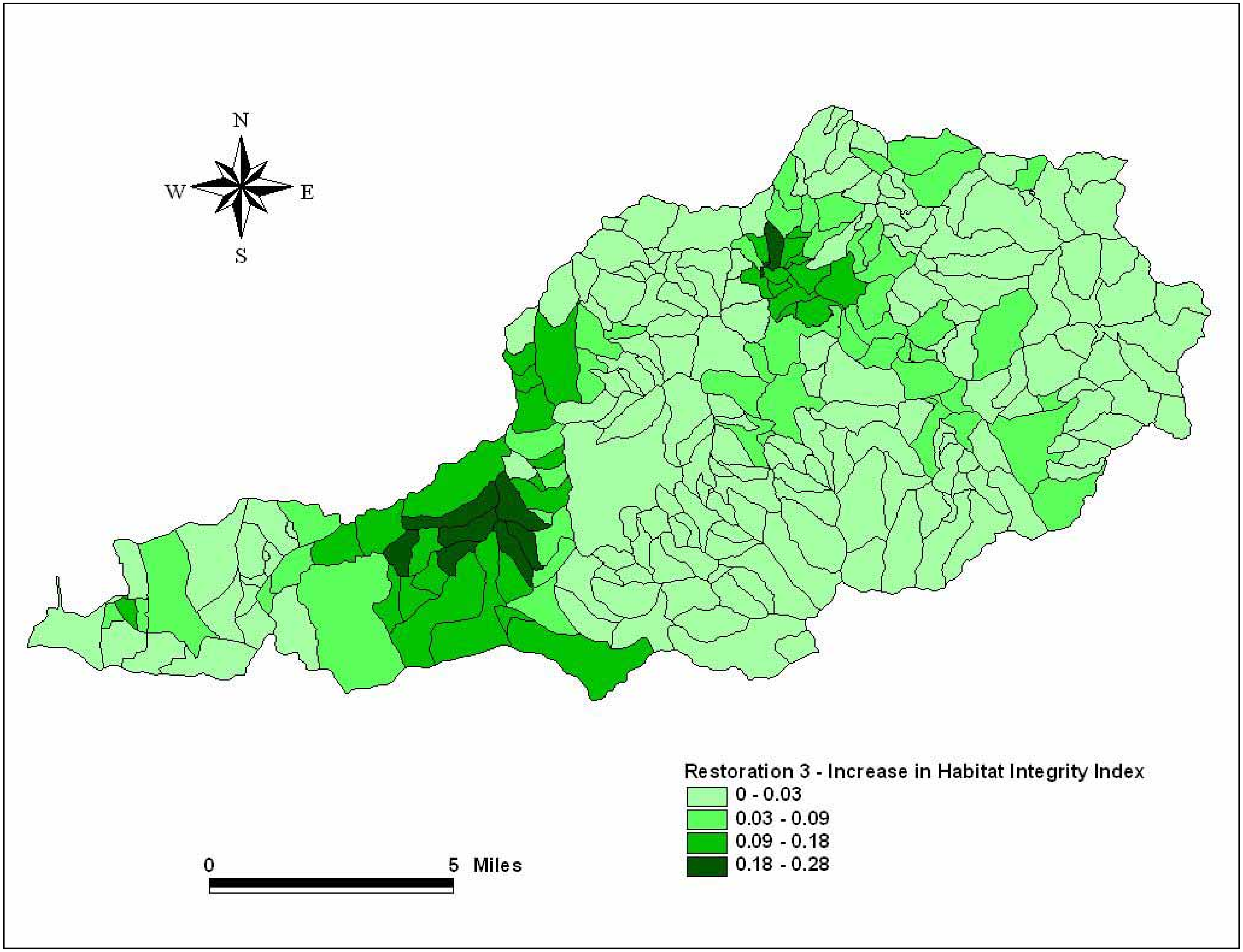

Figure 32. Increase in normalized habitat integrity index under Restoration Scenario 3 simulation

It is important to recognize that the three restoration scenarios presented represent only a small sample of the variety of scenarios 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. In addition, 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.

6.0 Literature Cited

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Appendix A: Reports, Spreadsheets, and ArcView Themes /Images Metadata

Reports, spreadsheets, and ArcView themes / images developed for this project are contained in folders on the attached CD. These folders and the shape files are described below. All shape files and images are in State Plane 83 Zone 6, with feet as the map unit. The "xxx" designates the various ArcView extensions attached to shape files created for each theme (i.e., dbf, shp, shx, etc.).

Report

This folder contains the final report in Microsoft Word and Adobe Acrobat formats. The report files are named:

otay restoration plan 060506.doc
otay restoration plan 060506.pdf

Spreadsheets

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

otay base wr 022906.xls

Local Drainages Theme

The shape file for the local drainage areas theme is named:

otay_ld_022906.xxx

Mainstem Channels Theme

The shape file for the mainstem channels is named:

otay_mstems_022906.xxx

The shape file for the mainstem channel tree is named:

otay_ldtree_022906.xxx

Mainstem Tributary Channels Theme

The shape file for the mainstem tributary channels is named:

otay_tribs_022906.xxx

Land Use / Land Cover Theme

The shape file for the land use / land cover is named:

otay_lulc_022906.xxx

Aerial Images

This folder contains aerial images for the study area. The source of these images is US Air Photo. They were taken in February of 2002. The file names for the Otay study area numbered from 1-59, and the files names for the CETAP study area are numbered as cetap1- cetap11. A number grid of the aerial photos is contained in:

otay_airgrid_022906.xxx

Digital Raster Graphic Images

This folder contains a digital raster graphic image for the study area from Sure Maps Raster. The file names is:

otay drg.xxx