Assessment of Riparian Ecosystem Integrity In the San Diego Creek Watershed, Orange County, California

Prepared for

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Special Area Management Plan

The Los Angeles District Corps of Engineers - Regulatory Branch is developing a Special Area Management Plan (SAMP) for the San Diego Creek Watershed of Orange County, California. The Los Angeles District is conducting the SAMP in coordination with the existing and the proposed amendment to the Central - Coastal 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" (Los Angeles District Corps of Engineers 1999) To achieve this goal, the aquatic resources within the San Diego Creek Watershed are being identified, characterized, delineated (Lichvar 2000), and assessed at a planning level.

Project Objective

The overall objective of this project was to conduct a baseline assessment of riparian ecosystem integrity in the San Diego Creek Watershed under current conditions. Once completed, the information developed during the assessment will be used to evaluate the potential impacts of future development projects on riparian ecosystems in the watershed. A similar project has been completed for the San Juan and San Mateo Creek Watersheds in Orange County (Smith 2000).

Three specific tasks were identified to meet the overall project objective. The first was to conduct a baseline assessment of riparian ecosystem integrity in the watersheds under current conditions. This was accomplished by dividing the riparian ecosystems into assessment units or “riparian reaches” and assessing each riparian reach using a suite of indicators of ecosystem integrity (see the Assessment Indicators and Assessment Procedure sections below). Establishing baseline conditions allows for a comparison between riparian ecosystem assessment units under current condition, and for a comparison of riparian ecosystem integrity under current and future conditions. Such comparisons will guide the decision-making process concerning future development projects by ensuring avoidance and minimization of impacts to these resources, both individually and cumulatively.

The second task was to rank riparian reaches in terms of ecosystem integrity. Ranking was based on the ecosystem integrity indicator scores and hydrologic, water quality, and habitat integrity indices resulting from the baseline assessment. The rankings will be one of many factors used to evaluate various alternatives within the watershed.

The third task, which has not yet been completed, will be to determine which of several proposed alternative development scenarios would result in the least impact to riparian ecosystem integrity in the watershed. This will be accomplished by comparing the assessment indicator scores and integrity indices of riparian reaches under baseline conditions with the scores and indices of riparian reaches following the “simulation” of each proposed alternative scenario. Simulations will be based on an implementation of the changes that can be expected to occur in the context of each assessment indicator as a result of each proposed alternative development scenario.

Background, Definitions, and Assumptions

Riparian Ecosystems

Riparian ecosystems are linear corridors of variable width that occur along perennial, intermittent, and ephemeral streams (Williams 1978). Two distinguishing features of riparian ecosystems are the hydrologic interaction that occurs between the stream channel and adjacent areas through the periodic exchange of surface and ground water, and the distinctive geomorphic features and vegetation communities that develop in response to this hydrologic interaction (Richards 1982; Harris 1987; Kovalchik and Chitwood 1990; Gregory et al. 1991; Malanson 1993; and Goodwin et al. 1997).

The hydrologic interaction between streams and adjacent areas typically results in two distinct zones, although either zone may be narrow and seemingly absent under certain geologic or geomorphic conditions. The first zone, the active floodplain, includes the areas that are inundated by overbank flooding at least once every five years. This zone exhibits the fluvial features associated with recurring flooding such as point bars, areas of scour, sediment accumulation, natural levees, and debris wrack, and vegetation communities that are either short lived or able to survive the effects of frequent flooding (Figure 1).

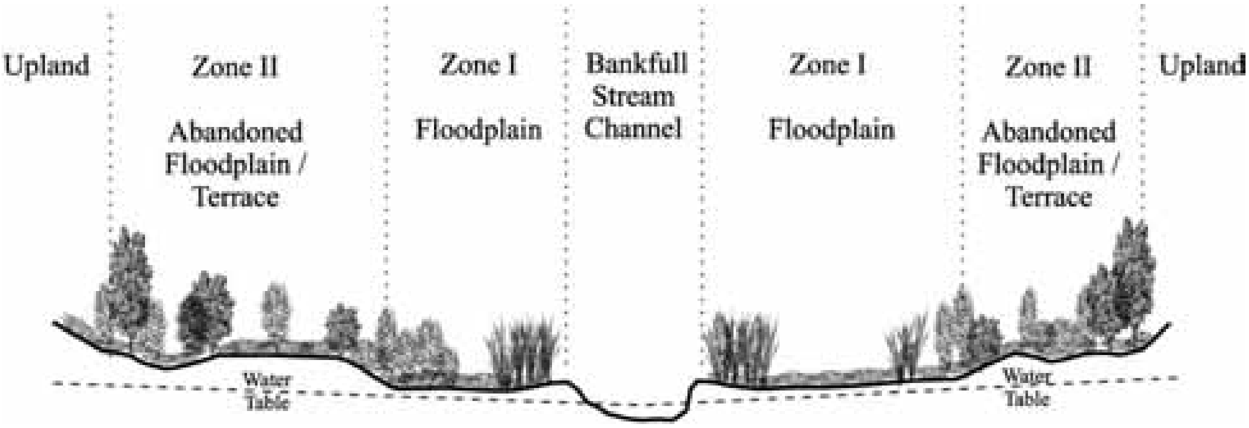

Figure 1. Generalized cross section of a riparian ecosystem

The second zone consists of abandoned floodplains and historical terraces formed by fluvial processes operating under different climatic conditions or hydrologic regimes (Knox et al. 1975; Graf et al. 1991; Rumsby and Macklin 1994). Under current climatic conditions and hydrologic regimes, these areas are only flooded during infrequent, larger magnitude events (Dunn and Leopold 1978). Vegetation communities in this zone are generally composed of woody perennials that rely on the higher water tables present in the riparian zone and capable of reestablishment after floods.

For the purposes of this project, riparian ecosystems were defined from a functional perspective as: the areas along perennial, intermittent, and ephemeral streams where the interaction with surface and groundwater results in distinctive geomorphic features and vegetation communities. Under natural circumstances, the riparian ecosystem includes the bankfull stream channel, active floodplain, and less frequently flooded abandoned floodplains/terraces.

Waters of the United States Including Wetlands versus Functional Riparian Ecosystems

Waters of the United States (WoUS) are the areas subject to regulation under Section 404 of the Clean Water Act (33 CFR Part 328.3). Wetlands are a subset of WoUS, and throughout this discussion, the term WoUS should be interpreted as including wetlands. The types of WoUS that occur in association with southern California riparian ecosystems typically include perennial, intermittent, ephemeral stream channels exhibiting a distinctive bed and bank, and wetland areas that meet the hydrologic, hydrophytic vegetation, and hydric soils criteria outlined in the Corps of Engineers Wetlands Delineation Manual (Environmental Laboratory 1987). .

It is important to note that the functional riparian ecosystem, as defined for this project, have no special recognition, meaning, or status in the context of the 404 Program. While functional riparian ecosystems normally include all WoUS regulated under the 404 Program and California Department of Fish and Game (CDFG) 1600 Program, the functional riparian ecosystem will often includes areas that do not fall under the jurisdiction of one or both of these programs. Consequently, there is not necessarily a one-to-one spatial correspondence between riparian ecosystems and WoUS in the watershed. This lack of spatial correspondence is common in the arid southwestern United States where the active floodplain portion of the riparian ecosystem often meets one or two of the delineation criteria, but fails to meet all three delineation criteria necessary to qualify as a regulated wetland, and abandoned floodplains / terraces frequently do not meet any of the delineation criteria.

The spatial inconsistency between WoUS and riparian ecosystems results from the relatively generic hydrologic, hydrophytic vegetation, and hydric soil delineation criteria developed for use in the wide variety of wetland types that occur in the United States. These generic delineation criteria necessarily ignore the unique way in which specific characteristics and processes contribute to the creation and maintenance of riparian as well as other functional wetland ecosystems. The intra- and inter-regional insensitivity of the generic delineation criteria is widely recognized. While the need for regionalization of delineation criteria has been identified (Committee on Characterization of Wetlands 1995), no solution to this formidable task has been developed, much less implemented.

The spatial inconsistency is problematic in the context of the mandate to assess functions of WoUS as part of the 404 permit review process. Clearly, an assessment cannot be accomplished by considering only the characteristics and processes of WoUS proper. This is because the functions of WoUS are significantly influenced by the characteristics of the entire riparian ecosystem, as well as the upland areas adjacent to the riparian ecosystem, and the drainage basin of the riparian ecosystem (Kratz et al. 1991; Hornbeck and Swank 1992; Bedford 1996).

A solution for meeting this challenge was outlined as part of the Hydrogeomorphic (HGM) Approach (Smith et al. 1995). In this approach, the functional ecosystem, as well as the adjacent landscape and drainage basin are considered during the assessment. However, when applying the results of the assessment in the context of the 404 permit review process, the results are applied only WoUS. This project used a similar approach in that the influence of the riparian ecosystem, adjacent uplands, and drainage basin were considered in assessing riparian ecosystem integrity. Consequently, when applying the results of the assessment, consistency with policies and assumptions of the SAMP, the 404 permit review process, Section 7 consultation, or the California Department of Fish and Game 1600 Program must be taken into account.

Riparian Ecosystem Integrity and Assessment Endpoints

Much has been written in the last few years about the concepts of ecological or ecosystem health and integrity (Rapport 1989; Costanza, Norton and Haskell 1991; Suter 1993; Scrimgeour and Wicklum 1996; Karr 1999). The two terms are often used interchangeably, however, the distinction made by Karr (1996) is instructive and important in interpreting and applying the mandate of the Clean Water Act. Health, refers to a flourishing condition, well being, and vitality (Guralnik and Friend 1968). Integrity, on the other hand, refers to the quality or state of being complete, and implies correspondence with a natural or original condition. Based on these distinctions, a cornfield, pine plantation, commercial nursery, and other culturally altered ecosystems qualify as healthy, but do not qualify as ecosystems with high integrity.

For this project, riparian ecosystems with high ecosystem integrity were defined as riparian areas that exhibit the full range of physical, chemical, and biological attributes and processes that characterized riparian ecosystems in the region over short and long term cycles prior to cultural alteration, and in addition, support a balanced, integrated, and adaptive biological community resulting from natural evolutionary and biogeographic processes.

While the abstract nature of the concept of ecosystem integrity makes it difficult to define, it makes it even more difficult to assess. This is because the concept of ecosystem integrity involves many characteristics and processes, and consequently there is no single, direct measure of ecosystem integrity. Thus, in order to focus on the most important characteristics and process contributing to ecosystem integrity, hydrologic, water quality, and habitat integrity were identified as three quantities of interest, or assessment “endpoints” to represent riparian ecosystem integrity (Liebowitz and Hyman 1999). The selection of these endpoints follows directly from the mandate in Section 101(a) of the Clean Water Act to “…restore and maintain the chemical, physical, and biological integrity of the Nation’s waters”. Each of the selected assessment endpoints is defined and discussed in greater detail in the Assessment Endpoint section below.

Selecting Metrics for Assessing Hydrologic, Water Quality, and Habitat Integrity

Once endpoints have been selected to represent ecosystem integrity, it is necessary to select metrics for assessing the endpoints. Two general types of metrics can be identified. “Direct metrics” are qualitative or quantitative measures the measure an endpoint directly. This type of metric is employed when assessment endpoints are narrowly defined, and a direct measure of the endpoint exists. Direct metrics cannot be used when that assessment endpoints are abstract concepts such as integrity because no direct measure of the endpoint exists.

The second type of metric is the “indirect metric” or “indicator”. Indicators are measures that are related (i.e., correlated) to the assessment endpoint in some way. Indicators must be used to assess complex or abstract endpoints for which no direct metric exists as discussed above. Indicators, however, are also frequently used when direct measures are too difficult or costly to measure. Many existing biological/ecological assessment methods use indicators for these reasons. For example, the Habitat Evaluation Procedure (USFWS 1980) has used habitat characteristics as indicators for more than 25 years to assess a “habitat suitability” endpoint in lieu of the more difficult and time consuming task of sampling animal populations directly (USFWS 1980). Indicators are used in a similar fashion in the Index of Biological Integrity (IBI) and related methods (Karr and Chu 1997), the instream flow incremental methodology (IFIM) (Bovee 1986), the Synoptic Approach (Leibowitz et al. 1992; Abbruzzese and Leibowitz 1997), and the Hydrogeomorphic (HGM) Approach (Smith et al. 1995).

Liebowitz and Hyman (1999) distinguish between “confirmed” and “judgment” indicators. Confirmed indicators are those in which the relationship between the indicator and endpoint can be precisely described (i.e., mathematically) with a known level of statistical confidence. Judgment indicators, on the other hand, are those in which the relationship between the indicator and endpoint is less precisely defined. The relationship might be based on trends or patterns published in the literature, observations in the field, or professional judgment. Given adequate time and research, many judgment indicators could be elevated to the status of a confirmed indicator. For example, it is possible to define a mathematical relationship between land use and water quality in the San Diego Creek Watershed as has been done in other watersheds (Hamlett et al. 1992). The key difference between confirmed and judgment indicators is the tradeoff that occurs in terms of the degree of certainty of the relationship between the indicator and endpoint, and the ability to obtain the information necessary to assess selected endpoints. Some authors question the use of judgment indicators (Conroy and Noon 1996, Schumaker 1996). However, from a practical, real world perspective, the use of judgement indicators is unavoidable given time and resource constraints, the lack of confirmed indictors, or the unavailability of quantitative data necessary to develop a confirmed indicator (Abbruzzese and Leibowitz 1997).

Each of the selected assessment indicators is defined and discussed in detail in the Assessment Indicators section below.

Reference Condition

In order to assess riparian ecosystem integrity a standard of comparison or “reference condition” must be defined. The reference condition serves two purposes. First, it provides a concrete and/or conceptual example of the conditions under which riparian ecosystems achieve and sustain a high level of integrity. It should be noted that the reference condition includes the conditions in the riparian ecosystem proper, as well as the lands adjacent and upstream of the riparian ecosystem that influence its integrity. Second, the reference condition provides a starting point from which to scale the relationship between the indicators and assessment endpoints.

Several different reference condition scenarios were suggested and considered for this project. These included the “culturally unaltered” and “least culturally altered” reference condition. In southern California riparian ecosystems, the culturally unaltered reference condition implies conditions that existed prior to grazing, agriculture, fire suppression, water resource management, transportation corridors, urbanization, and other cultural alterations that can be identified. It is synonymous with what McCann (1999) referred to as pre-Columbian, meaning the conditions that existed prior to the influence of European explorers and subsequent immigrants. The least culturally altered reference condition refers to those conditions that currently exist in a watershed or region and most closely reflect culturally unaltered conditions.

Culturally unaltered was selected as reference condition for this project for the following reasons. First, it represents the physical, chemical, and biological conditions under which riparian ecosystems have naturally evolved, and therefore, presumably represents the physical, chemical, and biological conditions that the Clean Water Act mandates should be maintained. While it can be argued that the culturally unaltered reference condition does not exist in southern California due to widespread existence of grazing, fire suppression, urban development, non-point air pollution, the disruption of historical metapopulation dynamics (Hastings and Harrison 1994), and a host of other factors, it is possible to make reasonable speculations as to what culturally unaltered conditions were like (Sedell and Luchessa 1981; Schubauer-Berigan 2000). It can also be argued that while it is impossible to restore culturally unaltered conditions, it may be feasible to restore some of the larger, isolated and remote areas to a condition that functionally approximates the culturally unaltered condition given adequate time and resources, and appropriate management.

In the restoration context, a reference condition based on the culturally unaltered scenario provides an appropriate target for restoring ecosystem integrity and function. On the other hand, a restoration target based on the least culturally altered reference condition provides an entirely arbitrary, and often inappropriate target with the potential to “successfully” restore riparian ecosystems with low ecosystem integrity and function, and no natural corollary.

Second, there is a generally unappreciated advantage, both in terms interpretation and comparability of results, to using the “absolute” standard of comparison represented by the culturally unaltered versus the “relative” standard of comparison represented by the least culturally altered reference condition. As an example of these advantages, consider the following scenario. Assessments of ecosystem integrity are done on riparian ecosystems in two watersheds, one heavily urbanized and the other a roadless wilderness. Two assessments are done in each watershed. The first assessment uses culturally unaltered conditions as reference conditions, and second uses least culturally altered conditions as reference conditions. Indices of ecosystem integrity are generated for both assessments ranging from 1 to 10 with an index of 1 indicating low integrity. In the first assessment, using culturally unaltered conditions as the reference condition, the indices for the urban watershed are likely to be at the lower end of the index range, while the indices for the wilderness watershed are likely to be in the higher end of the index range. These results are intuitively reasonable, and in reality correct, because heavily urbanized watersheds have significantly less ecosystem integrity than wilderness area watersheds due to changes in land use, stream channelization, loss of habitat, and other factors.

Now consider the results for the second assessment using least culturally altered conditions as the reference condition. Indices for the urban watershed will be at the high end of the index range, because least culturally altered conditions, specific to the urban watershed, were used to scale indicators of ecosystem integrity. Indices for the wilderness watershed will be at the high end of the index range for the same reason. However, these results are not intuitive because, using the foregoing definition of ecosystem integrity, the urban watershed in reality has a lower level of ecosystem integrity than the wilderness area, despite the fact that the indices of ecosystem integrity indicate there is little difference between the two. The non-intuitive nature of these results, and the inability to compare areas makes the use of the relative, least culturally altered reference condition, problematic at best.

The third reason for selecting culturally unaltered as the reference condition was the ability to define a culturally unaltered condition for the indicators of riparian ecosystem integrity without extensive reconnaissance in the watershed prior to conducting the assessment. For example, in the case of the indicators related to land use, it was reasonable to assume that under the culturally unaltered condition no grazing, agriculture, transportation, or urban development land uses existed. Similarly, in the case of the altered hydrologic conveyance indicator, it was reasonable to assume that under culturally unaltered conditions, stream channels were straightened, lined, impounded, or underground. The same could not be said for defining the least culturally altered condition. In order to define least culturally altered condition for assessment indicators it would have be necessary to conduct reconnaissance in the watershed, prior to conducting the assessment, to determine the range of cultural alteration that existed and what represented least culturally altered condition.

Assessment Endpoints

The assessment endpoints selected to represent riparian ecosystem integrity for this project were hydrologic integrity, water quality integrity, and habitat integrity. The following sections define these endpoints and discuss them in terms of assessment indicators. Each of these indicators is specifically defined and discussed in greater detail in the Assessment Indicators Section below.

Hydrologic Integrity

Hydrologic integrity was defined as exhibiting a range of frequency, magnitude, and temporal distribution of stream discharge along with a concomitant surface and subsurface interaction with the floodplain that historically characterized riparian ecosystems in the region (Bedford 1996, Poff et al. 1997, Richter et al. 1997). In the arid southwest, this translates into seasonal intermittent, ephemeral, or low flow periods, with annual bankfull discharges superimposed on a background of episodic, and often catastrophic, larger magnitude floods that inundate historical terraces (Graf 1979; Graf 1988; Harris 1987; Fisher et al. 1982; Friedman et al. 1996a, Friedman et al. 1996b).

In selecting indicators to assess the hydrologic integrity endpoint, two groups of characteristics and processes were considered. The first group focused on the factors that influence the frequency, magnitude, and temporal distribution of stream discharge, and the second group focused on the factors that influenced the hydrologic linkage between the stream channel and the active floodplain and adjacent terraces. Direct measures of stream discharge are unavailable at the riparian reach scale in these watersheds. Consequently, several indicators were selected at the drainage basin scale with the assumption that an indirect estimate of deviation from reference condition can be made based on changes in of specific characteristic and processes of a drainage basin such as precipitation, interception, infiltration, evapotranspiration, percolation, groundwater flow, and surface water flow overland and in channels. Cultural alteration of the drainage basin changes these characteristics and processes and consequently stream discharge. While it is difficult to quantify the exact nature of the relationship between specific drainage basin characteristics, as represented by the indicators, and stream discharge, it can generally be shown that as cultural alteration in a watershed increases, so does the deviation from short and long-term historical patterns of frequency, magnitude, and distribution of stream discharge.

The four indicators of hydrologic integrity selected to reflect degree of cultural alteration in a drainage basin with the potential to influence stream discharge included:

- Altered Hydraulic Conveyance – Drainage Basin
- Surface Water Retention
- Perennialized Stream Flow
- Import, Export, or Diversion of Surface Water

The fact that the frequency, magnitude, and distribution of stream discharge in a riparian reach is similar to historical range of conditions does not alone ensure hydrologic integrity. This is because hydrologic integrity also depends on maintaining interaction between the stream channel and the floodplain and adjacent terraces of the riparian ecosystems through overbank and subsurface hydrologic interaction. This interaction is critical to the maintenance of riparian plant communities, sediment storage, carbon dynamics, biogeochemical processes, and other characteristics and processes of riparian ecosystems.

Two indicators were selected to represent the degree of interaction between the stream channel and the floodplain included:

- Altered Hydraulic Conveyance – Riparian Reach
- Floodplain Interaction

Water Quality Integrity

Water quality integrity was defined as exhibiting a range of loading in the pollutant categories of nutrients, pesticides, hydrocarbons, and sediments that are similar to those that historically characterized riparian ecosystems in the region. Assessing changes in the range of loading in each pollutant category can be determined directly by comparing data on current loading with data on historical loading when such data is available. While there is some historical and recent monitoring data available for a limited number of stations in the watershed, little or no loading data is available at the riparian reach scale. Consequently, the assessment of water quality integrity was based on indicators of drainage basin and riparian reach characteristics that have been shown to influence water quality integrity.

Three groups of factors were considered in selecting indicators of water quality integrity endpoint. The first group focus on whether or not the changes in land use in the drainage basin had the potential to increase sources of pollution compared to the reference condition. The second group focused on whether or not the stream channel delivery system had changed in relation to reference condition in terms of frequency, magnitude, and temporal distribution of stream flow (Kuenzler 1977). The third group focused on whether or not changes in land use in the areas adjacent to the stream, or the loss of a hydrologic connection between the stream channel and the floodplain had decreased the likelihood of pollutants being physically captured or biogeochemically processed compared to reference condition. A number of studies have shown that cultural alteration of these factors can lead to increased loading in one or more pollutant categories (Osborne and Wiley 1988; Allan and Flecker 1993; Hunsaker and Levine 1995; Perry and Vanderklein 1996; Richards et al. 1996; Allen et al. 1997; Bolstad and Swank 1997; Johnson et al. 1997; Wang et al. 1997; Miltner and Rankin 1998; Trimble 1997; Basnyat et al. 1999).

Four indicators of water quality were selected to reflect the condition of in land use in the drainage basin. They included:

- Land Use / Land Cover – Nutrient Increase
- Land Use / Land Cover – Pesticide Increase
- Land Use / Land Cover – Hydrocarbon Increase
- Land Use / Land Cover – Sediment Increase

Five indicators were selected to reflect the condition of the stream system that transports pollutants. They are the same indicators used to assess hydrologic integrity with the exception of Floodplain Interaction and included:

- Altered Hydraulic Conveyance – Riparian Reach
- Altered Hydraulic Conveyance – Drainage Basin
- Surface Water Retention

- Perennialized Stream Flow
- Import, Export, or Diversion of Surface Water

Three indicators of water quality were selected to reflect the condition of riparian ecosystem with respect to it ability to physically capture and biogeochemically process pollutants. They include:

- Floodplain Interaction
- Sediment Regime
- Area of Native Riparian Vegetation

Habitat Integrity

Riparian ecosystems with habitat integrity exhibit the quality and quantity of habitat necessary to support and maintain a balanced, integrated, adaptive biological system having the full range of characteristics, processes, and organisms at the site specific, landscape, and watershed scales that historically characterized riparian ecosystems in the region. Several factors were considered in selecting indicators of habitat integrity including the spatial extent and quality of riparian habitat, the "connectedness" of riparian habitats at the riparian reach and drainage basin scales, and the spatial extent and quality of upland habitat in the landscape adjacent to riparian ecosystems.

- Area of Native Riparian Vegetation
- Riparian Corridor Continuity – Riparian Reach
- Riparian Corridor Continuity – Watershed
- Land Use / Land Cover - Riparian Ecosystem Boundary
- Land Use / Land Cover - Upland Buffer

Assessment Indicators

The selection of assessment indicators was based primarily on the identification of important characteristics and processes believed to influence assessment endpoints. Potential indicators were gleaned from a review of using existing assessment methods (Dinius 1987; Lee et al. 1997; Ladson et al. 1999). Further investigation of the literature on riparian ecosystems, and the field observations and collective experience of individuals participating in the project provided additional potential indicators. In selecting indicators, the objective was to directly or indirectly capture to the greatest degree possible the full range of characteristics and processes that influence hydrologic, water quality, and habitat integrity of riparian ecosystems at the riparian ecosystem, adjacent upland, and drainage basin.

Several other factors influenced the final selection process. First, was the need to match the project objectives of establishing baseline conditions and the ability to make comparisons between riparian ecosystems with available data, time and resources. Other factors included the large project area (>450 km^2), a short time frame and limited budget, the lack of quantitative data at the riparian reach assessment unit scale, and the lack of existing confirmed indicators. Another factor was the requirement to develop an open and easily understood approach that would allow participation and input from multiple stakeholders representing a range of perspectives from the development community to federal agencies charged with the protection of sensitive, threatened, and endangered species. Ultimately, a balancing of all these factors led to the selection of the indicators described below.

Each of the following sections defines an assessment indicator and discusses the relationship between the indicator and relevant endpoints. In addition, the method used to measure the indicator and assign an indicator value is described, along with the reference condition and range of indicator values used to assign indicator scores.

Altered Hydraulic Conveyance – Riparian Reach and Drainage Basin (AHC_{RR} / AHC_{DB})

Altered Hydraulic Conveyance indicates the degree to which engineering techniques have been used to “improve” the capacity of channels in a riparian reach or drainage basin to convey surface water downstream. The engineering techniques involve reducing the frictional resistance (i.e., roughness) caused by channel substrate, vegetation, woody debris, and other objects in the channel (Barnes 1967), minimizing the wetted perimeter, and/or shortening the length of a channel. Specific techniques include dredging, straightening, hardening, and lining of the stream channel as well as the removal of vegetation (Galay 1983, Brookes 1988).

Increasing the volume of water and velocity at which water is conveyed downstream can result in a significant change in the hydrologic regime, and hence hydrologic integrity, in the riparian reach where the alteration occurs as well as in upstream and downstream reaches. For example, removal of vegetation decreases channel stability and increases erosion by reducing the resistance afforded by the network of plant roots, and by increasing the velocity and consequently the erosive force of water in the channel. A straightened stream reach will typically respond by incising to reestablish a more energy efficient and stable channel slope (Shankman and Samson 1991). This in turn initiates headcutting and increased erosion upstream. Downstream of an altered stream channel the hydrologic regime can also be affected in terms of increased peak discharges, a decrease in channel stability, and an increase in erosion due to increased water velocity.

This indicator was measure as the percent of the mainstem channel through the riparian reach with altered hydraulic conveyance. At the riparian reach scale, aerial photography and field observations were used to estimate the value of the metric. At the drainage basin scale, the indicator was calculated as the weighted average of the percent of altered hydraulic conveyance for all riparian reaches in the drainage basin of the riparian reach. In other words,

$$\sum_{i=1}^{i_n}\left[\frac{AHC_{RR} * \left({}^{ML_{RR}}\!\big/_{ML_{DB}}\right)}{100}\right] \tag{1}$$

Where: AHC_{RR} = % of mainstem in a riparian reach with altered hydraulic conveyance

ML_{RR} = Length of mainstem channel in a riparian reach

ML_{DB} = Length of mainstem channel of all riparian reaches in drainage basin

The reference condition was defined as <5% of the mainstem channel in riparian reach with altered hydraulic conveyance. Indicator scores were assigned based on range of indicator values in Table 1

Table 1. Range of indicator values for scaling the altered hydraulic conveyance indicator

Indicator Value Range	Score
< 5% of riparian reach mainstem/drainage basin with AHC	5
∃5 and #15% of riparian reach mainstem/drainage basin with AHC	4
>15 and #30% of riparian reach mainstem/drainage basin with AHC	3
>30 and #50% of riparian reach mainstem/drainage basin with AHC	2
>50% of riparian reach mainstem/drainage basin with AHC	1

Surface Water Retention (SWR)

Surface Water Retention indicates the degree to which the hydrologic regime in a riparian reach has been altered as a result of short and long-term storage of surface water in reservoirs, lakes, sediment basins, retention ponds, and similar surface water storage facilities. Streams in arid regions are disturbance-dominated systems (Resh et al. 1988; Power et al. 1988, 1996; Rood and Mahoney 1990). During flash floods, stream discharge can increase by several orders of magnitude causing aquatic organism mortality, destruction of riparian vegetation, and changes in channel morphology. The biological components of riparian ecosystems have adapted to these episodic cycles of disturbance, and developed a variety of mechanisms that make it possible to survive and indeed flourish where other organisms cannot. Short and long-term retention of surface water in storage facilities can significantly alter the characteristic pattern of discharge over the water year (Cushman 1985; Bain et al. 1988; Dynesius and Nilsson 1994; Ligon et al. 1995; Poff et al. 1997; Hadley and Emmett 1998). Most importantly, it eliminates the low frequency, high volume discharges that reset the system (Hawkins et al. 1997). However, it can also lead to perennialization of streamflow, change the pattern of seed distribution, germination, and survival, and change a variety of other physical and biological processes necessary to perpetuate the riparian ecosystem (Hynes 1975; Warren 1979; Lotspeich and Platts 1982; Frissell et al.1986; Kondolf et al.1987; Debano and Schmidt 1989; Stromberg and Patton 1991; Johnson 1994; Power et al. 1996; Kershner 1997; Kondolf 1997; Richter et al. 1997).

This indicator was measured as the percent of the drainage basin of a riparian reach upstream of a lake, reservoir, dry dam, sediment basin, retention pond, or similar facility capable of storing surface water from several days to months. The total area within each drainage basin upstream of the downstream extent of all storage facilities was determined using the ArcView GIS themes of riparian reaches, surface water retention facilities, and USGS 7.5 minute topographic map. Using the theme of surface water retention structures and a topographic map as background, the reach theme was split along topographic boundaries at the downstream extent of the retention structures. Upstream areas above these reach segments were calculated and summed across the drainage basin to determine the metric value.

The reference condition was defined as <5% of the drainage basin of a riparian reach upstream of a lake, reservoir, dry dam, sediment basin, retention pond, or similar facility capable of storing surface water from several days to months. Indicator scores were assigned based on the range of indicator values in Table 2.

Table 2. Ranges of indicator values for scaling the surface water retention indicator

Indicator Value Range	Score
#5% of drainage basin drains to surface water storage facilities	5
>5 and #15% of drainage basin drains to surface water storage facilities	4
>15 and #30% of drainage basin drains to surface water storage facilities	3
>30 and #50% of drainage basin drains to surface water storage facilities	2
>50% of drainage basin drains to surface water storage facilities	1

Perennialized Stream Flow (PSF)

Perennialized Stream Flow indicates the degree to which the hydrologic regime of a riparian reach has been altered by a supplementary supply of surface water resulting from cultural activites such as irrigation. Perennialization refers to the conversion of intermittent or ephemeral stream channels to a perennial stream through the addition of surface water flow (usually at low levels) in a stream channel from artificial supplies of surface water. The supply of water usually occurs in the form of irrigation or treated return water. In arid regions, perennialization facilitates a shift in plant and animal community composition away from what normally occurs in a riparian reach that is not perennialized. Perennialization also has the potential to affect physical and chemical processes in riparian ecosystems.

This indicator was measured as the percent of the mainstem channel through a riparian reach that exhibited perennialized stream flow due to supplementary sources of water at the time of the field visits, or showed evidence of perennialized stream flow (i.e., occurrence of *Typha* sp., *Carex* sp. and/or other emergent aquatic species). Field observations and aerial photographs were used to assign a value to the indicator. The types of evidence used to identify a stream as perennialized was the presence of low flow during dry periods. Other types of evidence included nutrient enrichment based on the presence of blue-green algae and vascular species such as *Typha* sp., outfall pipes and other inlet structures entering a reach, residential developments and golf courses in the drainage basin, interbasin transfer import points, and the lack of evidence of a natural source of low flow.

The reference condition was defined as <5% of the mainstem channel of a riparian reach with perennialized stream flow. Indicator scores were assigned based on the range of indicator values in Table 3.

Table 3. Range of indicator values for scaling the perennialized stream flow indicator

Indicator Value Range	Score
< 5% of stream channel exhibiting perennialized flow	5
∃5 and #15% of stream channel exhibiting perennialized flow	4
>15 and #30% of stream channel exhibiting perennialized flow	3
>30 and #50% of stream channel exhibiting perennialized flow	2
>50% of stream channel exhibiting perennialized flow	1

Import, Export, or Diversion of Surface Water (IED)

Import, Export, or Diversion of Surface Water indicates the degree to which the hydrologic regime of a riparian reach has been altered as a result of import, export, or diversion of surface water. Inter-basin import and export of surface water, and the intra-basin diversion of water for public water supply, irrigation, and ground water recharge is common in the arid western United States. The import, export, or diversion of water within and between watersheds has been shown to affect a wide variety biotic and abiotic processes as a result of changes in the quantity and timing of surface water discharge and other aspects of the hydrologic regime (Taylor 1982; Kondolf et al. 1987; Stromberg and Patten 1990; Petts 1996; Davies, Thoms, and Meador 1992)

This indicator was measured as the percent of a riparian reach drainage basin from which surface water was imported, exported, or diverted on a continuous or periodic basis. In the case of imported water, the area of the watershed from which water was being imported was added to the area of the riparian reach drainage basin receiving water prior to calculating the percentage of the drainage basin that contributed to import. Using the ArcView GIS theme of riparian reaches and USGS 7.5 minute topographic map images the area below import, export, or diversion points were calculated and summed across the drainage basin to determine the metric value.

The reference condition was defined as <5% of the drainage basin of a riparian with surface water continuously or occasionally imported, exported, or diverted. Indicator scores were assigned based on the range of indicator values in Table 4.

Table 4. Range of indicator values for scaling the import, export, or diversion of water indicator

Indicator Value Range	Score
< 5% of drainage basin with import, export, or diversion of water	5
∃5 and #15% of drainage basin with import, export, or diversion of water	4
>15 and #30% of drainage basin with import, export, or diversion of water	3
>30 and #50% of drainage basin with import, export, or diversion of water	2
>50% of drainage basin with import, export, or diversion of water	1

Floodplain Interaction (FI)

Floodplain Interaction indicates of the degree to which the overbank hydrologic connection between the bankfull channel and the active floodplain of the riparian ecosystem has been severed in a riparian reach. Many of the characteristics and processes of riparian ecosystems are dependent on periodic hydrologic interaction between the stream channel and the floodplain. When a hydrologic connection is lost, regardless of the reason, the physical and biological characteristics of the riparian ecosystem change.

This indicator was measured as the percent of the mainstem channel through a riparian reach that was physically disconnected from the floodplain as a result of culturally accelerated channel erosion/incision, channel improvements, or levees. An incised mainstem channel in which an active floodplain had been reestablished within the incised channel through normal fluvial processes was not considered to be disconnected (Keller 1972). If one side of the channel was disconnected from the floodplain, then 50% of the stream channel was considered disconnected. If both sides of the channel were disconnected from the floodplain, then 100% of the stream channel was considered disconnected. Aerial photography and field observations were used to estimate the value of the metric.

The reference condition was defined as <5% of the mainstem stream channel disconnected from the floodplain. Indicator scores were assigned based on the range of indicator values in Table 5.

Table 5. Range of indicator values for scaling the floodplain interaction indicator

Indicator Value Range	Score
< 5% of mainstem stream channel disconnected from the floodplain	5
∃5 and #15% of mainstem stream channel disconnected from the floodplain	4
>15 and #30% of mainstem stream channel disconnected from the floodplain	3
>30 and #50% of mainstem stream channel disconnected from the floodplain	2
>50% of mainstem stream channel disconnected from the floodplain	1

Sediment Regime (SR)

Sediment Regime indicates the degree to which the sediment dynamics in the mainstem channel of a riparian reach are in equilibrium with respect to the supply of sediments from upstream sources and erosion and deposition processes within the channel. A variety of cultural activities can alter sediment dynamics and/or channel geometry. These types of changes include channel erosion due to physical disturbance, channel incision and head-cutting due to the alteration of slope, channel aggregation due structures that impede flow (i.e., weirs, drop structures, culverts), and irrigation diversions (Kondolf et al. 1987).

This indicator was assigned a score by matching field observations to the descriptions in Table 6.

The reference condition was defined as exhibiting a sediment regime that was in equilibrium with respect to supply, erosion, and deposition processes, and not affected by cultural alteration.

Table 6. Description of Conditions for assigning sediment regime indicator score

Description of Conditions	Score
Movement of sediment in the channel is in equilibrium in terms of supply, erosion, and deposition processes, and does not appear to have been affected by cultural alteration. On higher-order streams there are alternating point bars; bank erosion occurs, but is stabilized and moderated by vegetation; and channel width, form, and floodplain area is consistent through the reach. In low-order streams with bedrock control, some of these indicators may not be apparent, but overall bank and hillslope erosion is moderated by vegetation, and there are no apparent culturally induced catastrophic failures.	5
Movement of sediment in the channel is in equilibrium with the current hydrologic regime, and exhibits an overall balance in terms of erosion and deposition processes. On higher-order streams there are alternating point bars; bank erosion occurs, but is stabilized and moderated by vegetation; and channel width, form, and floodplain area is consistent through the reach. In low-order streams with bedrock control, some of these indicators may not be apparent, but overall bank and hillslope erosion is moderated by vegetation, and there are no apparent culturally induced catastrophic failures.	4
Sediment disequilibrium minor and localized within the reach. This includes small, localized areas of bank protection, slumping, or encroachment on the floodplain and channel. This condition class also includes previously disrupted reaches on a recovery trajectory, such as deeply entrenched streams where downcutting has been arrested by structural grade control, and there is sufficient room for lateral channel migration and establishment of a functional floodplain within the incised channel.	3
Sediment erosion and deposition out of equilibrium. Water inflow is sediment rich or poor, or accelerated bank erosion exists. Channel not actively incising, but extensive disequilibrium is evident. Typical indicators include extensive bank slumping (erosion events that exceed any moderating influence of native vegetation), active gullies feeding into the reach from adjacent hillslopes, shoaling of sediments rather than deposition in sorted lateral and mid-channel bars. Apparently stable channels should be placed in this category if there is evidence of regular mechanical disruption, such as bulldozing of the channel bottom and clearing of riparian vegetation to improve flood conveyance.	2
Sediment dynamics within most of the reach are seriously disrupted. This includes reaches where there is no significant storage or recruitment of sediment (i.e., reaches in underground tunnels/culverts, and reaches hardened with rock or concrete). It also includes reaches that are either actively incising or functioning as sediment traps (e.g., sediment basins). This also includes reaches that have been subject to recent changes likely to induce severe disequilibrium, such as extensive floodplain filling, change in slope, channel straightening, or other changes that are likely to cause channel downcutting during future high-flow events.	1

Land Use / Land Cover – Nutrient/Pesticide/Hydrocarbon/Sediment Increase ($LULC_N$)

Land use / land cover (LULC) indicates the way in which a tract of land is utilized, has been developed, or the physiognomic class of vegetation. For example, a tract of land that is used to produce row crops is assigned an agricultural LULC, golf courses and parks are assigned to a recreational or open space LULC, urban areas are typically assigned to a residential, industrial, or commercial LULC. Lands supporting natural vegetation communities (i.e., chaparral versus pasture) are assigned to a shrub, forest, or grassland LULC. A variety of LULC classifications have been developed over the years. Today however, the reference to LULC usually implies the USGS classification of LULC (Anderson et al. 1976) or a similar, but more detailed regional variations of this classification. This type of LULC classification is typically developed through the interpretation of aerial photographs or the analysis of other remote sources of thematic information (USGS 1990).

Over the centuries, humans have modified the LULC of the natural landscape through intensive land management practices such as agriculture, forestry, and grazing, as well as through industrialization and urbanization. The net effect of these activities has been a dramatic shift in the type and extent of LULC that occur around the world today, particularly in developed countries (Meyer and Turner 1992; Hannah et al. 1994.

A number of studies have related LULC to water quality. While they have consistently shown that the water quality decreases as natural LULC are culturally altered, they specific relationships and causative factors vary widely. For example, Hunsaker and Levine found that LULC changes in the watershed had the greatest effect on water quality, while Graf 1998 found that changes in LULC in the surrounding landscape had the greatest effect. The relationship between LULC and quantity and quality of surface water has been documented for a variety of wetland and aquatic systems (Brugham 1978; Ehrenfield 1983; Kuenzler 1986; Howarth et al. 1991; Ryan 1991; Williamson et al. 1992; Richards and Host 1994; Cooper 1995; Blair 1996; Wilber et al. 1996; Caruso and Ward 1998). In the western United States specifically, livestock grazing, agriculture, and urbanization have often been identified as contributors to increased surface water runoff and non-point sources of sediment, nutrients, and other classes of pollutants (Armour et al. 1991; Sedgwick and Knopf 1991; Charbonneau and Kondolf 1993; Bush and Smith 1995; Rothrock et al. 1998).

The four LULC indicators were measured as the percent of the drainage basin of a riparian reach with LULC types with the potential to increase the nutrient, pesticide, hydrocarbon, or sediment loading in downstream surface waters. Land use / land cover categories with the potential to increase these categories of pollutants are shown in Table 7. Using the ArcView GIS themes of riparian reach and LULC themes, the area of a drainage basin occupied by each LULC was determined for each indicator. The area of LULC types with the potential to increase pollutants, hydrocarbons, nutrients, and sediment were then summed across the drainage basin and divided by the total drainage basin area to determine the metric value.

The reference standard condition was defined as <5% of the watershed and surrounding landscape area with LULC types with the potential to increase nutrient, pesticide, hydrocarbon, or sediment loading in surface waters downstream. Indicator scores were assigned based on the range of indicator values in Table 8.

Table 8. Range of indicator values for scaling the land use / land cover indicators

Indicator Value Range	Score
< 5% of watershed / landscape with LULC types that increase N/P/H/S	5
∃5 and #15% of watershed / landscape with LULC types that increase N/P/H/S	4
>15 and #30% of watershed / landscape with LULC types that increase N/P/H/S	3
>30 and #50% of watershed / landscape with LULC types that N/P/H/S	2
>50% of watershed / landscape with LULC types that increase N/P/H/S	1

Area of Native Riparian Vegetation (NRV)

Area of Native Riparian Vegetation indicates the degree to which native riparian vegetation communities occupy the floodprone area of the mainstem channel through a riparian reach. Much has been written about the importance of native riparian vegetation communities in the support of specific faunal groups such as amphibians (Brode and Bury 1984), birds (Hendricks and Rieger 1989), and fauna in general (Hubbard 1977; Faber et al. 1989; Knopf et al. 1988).

This indicator was measured as the percent of floodprone area along the mainstem channel of the riparian reach occupied by native riparian vegetation communities. Under culturally unaltered conditions, a complex interaction of many factors such as the size of the watershed, discharge, channel geometry, substrate type, and slope determine the size of the area that

Table 7. Land Use / Land Cover (LULC) types

LULC Code	LULC Description	Increase in LULC Type Increases Runoff	Increase in LULC Type Increases Nutrient Load	Increase in LULC Type Increases Pesticide Load	Increase in LULC Type Increases Hydrocarbon Load	Increase in LULC Type Increases Sediment Load	Increase in LULC Type Inhibits Animal Use / Movement
11	Residential	Yes	Yes	Yes	Yes	No	Yes
12	Commercial and Services	Yes	Yes	Yes	Yes	No	Yes
13	Industrial	Yes	Yes	Yes	Yes	No	Yes
14	Transportation/Commercial/Utilities	Yes	Yes	Yes	Yes	No	Yes
15	Industrial and Commercial	Yes	Yes	Yes	Yes	No	Yes
16	Mixed Urban and Built-Up	Yes	Yes	Yes	Yes	No	Yes
17	Other Urban or Built-Up	Yes	Yes	Yes	Yes	No	Yes
21	Cropland and Pastureland	Yes	Yes	Yes	No	Yes	Yes
22	Orchards/Vinyards/Nurseries	Yes	Yes	Yes	No	Yes	Yes
23	Confined Feeding Operations	Yes	Yes	No	No	Yes	Yes
24	Other Agricultural Land	Yes	Yes	Yes	No	Yes	Yes
31	Herbaceous Rangeland	Yes	Yes	Yes	No	Yes	Yes
32	Shrub and Brush Rangeland	Yes	Yes	Yes	No	Yes	No
33	Mixed Rangeland	Yes	Yes	Yes	No	Yes	Yes
41	Deciduous Forest Land	No	No	No	No	No	No
42	Evergreen Forest Land	No	No	No	No	No	No
43	Mixed Forest Land	No	No	No	No	No	No
52	Lakes	No	No	No	No	No	No
53	Reservoirs	No	No	No	No	No	No
54	Bays and Estuaries	No	No	No	No	No	No
61	Forested Wetlands	No	No	No	No	No	No
62	Nonforested Wetlands	No	No	No	No	No	No
71	Dry Salt Flats	No	No	No	No	No	No
72	Beaches	No	No	No	No	No	No
73	Sandy Areas (non-Beach)	No	No	No	No	No	No
74	Exposed Rock	No	No	No	No	No	No
75	Strip Mines	Yes	Yes	Yes	Yes	Yes	Yes
76	Transitional Areas	Yes	Yes	Yes	Yes	Yes	Yes

typically supports riparian vegetation. In general however, as stream orders increase, the width of the bankfull channel increases, and the size of the area supporting riparian vegetation increases. Floodprone area represents a scaled metric that can be applied consistently in different stream orders throughout a watershed. Floodprone area was determined in the field by projecting the elevation corresponding to two times the maximum depth of the bankfull channel until it intersected the surface of theadjacent floodplain / terrace on both sides of the mainstem channel (Rosgen 1996; 5-20). The percent of floodprone area occupied by native riparian vegetation was estimated based on field observations, aerial photographs, and riparian vegetation communities mapped by Lichvar (2000).

The reference condition was defined as >95% of the floodprone width of the mainstem channel through the riparian reach occupied by native riparian vegetation communities. Indicator scores were assigned based on the range of indicator values in Table 9.

Table 9. Range of indicator values for scaling the native riparian vegetation indicator

Indicator Value Range	Score
>95% of floodplain occupied by riparian vegetation communities	5
#95 and >85 and % of floodplain occupied by riparian vegetation communities	4
#85 and >70 and % of floodplain occupied by riparian vegetation communities	3
#70 and >50 and % of floodplain occupied by riparian vegetation communities	2
<50% of floodplain occupied by riparian vegetation communities	1

Riparian Corridor Continuity – Riparian Reach and Drainage Basin (RCC_{RR} / RCC_{DB})

Riparian Corridor Continuity indicates the degree to which the mainstem channel of a riparian reach exhibits an uninterrupted vegetated riparian corridor. Riparian ecosystems typically form a relatively continuous corridor along the stream channel and floodplain. Intact vegetated corridors allow animals to move to locations throughout a watershed on a daily, seasonal, or annual basis (La Polla and Barrett 1993; Machtans et al. 1993; Naiman et al. 1993 and 1996), but see Simberloff et al. (1992). Gaps in the continuous riparian corridor can occur as a result of natural fluvial processes during large magnitude events (Hawkins et al. 1997). However, gaps are more frequently created as a result of cultural alterations such as roads, power and pipeline corridors, agriculture activities, and urban/industrial development.

This indicator was measured at the riparian reach scale as the percent of floodprone area along the mainstem channel of the riparian reach occupied by native and non-native vegetation communities with adequate height and structure to allow faunal movement. For example, annual grassland with no shrub or tree component was considered to represent a corridor gap. The difference between this indicator and Area of Native Riparian Vegetation was that for the RCC - RR indicator, the vegetation corridor could be composed of native or non-native riparian species, whereas for the ANRV indicator, only native riparian vegetation communities were considered. The percent of floodprone area occupied by native riparian vegetation was estimated based on field observations, aerial photographs, and riparian vegetation communities mapped by Lichvar (2000). At the drainage basing scale, Riparian Corridor Continuity was calculated as the weighted average of the percent of Riparian Corridor Continuity for all riparian reaches in the drainage basin of the riparian reach. In other words,

$$\sum_{i=1}^{i_n}\left[\frac{RCC_{RR} * \left({}^{ML_{RR}} / {}_{ML_{DB}} \right)}{100}\right] \qquad (2)$$

Where: RRC_{RR} = % of mainstem in a riparian reach with vegetation corridor gaps

ML_{RR} = Length of mainstem channel in a riparian reach

ML_{DB} = Length of mainstem channel of all riparian reaches in drainage basin

The reference condition was defined as <5% of the floodplain of the mainstem channel of the riparian reach occupied with riparian vegetation communities. Indicator scores were assigned based on the range of indicator values in Table 10.

Table 10. Range of indicator values for scaling the riparian corridor continuity indicators

Indicator Value Range	Score
< 5% of riparian reach with gaps / breaks due to cultural alteration	5
∃5 and #15% of riparian reach with gaps / breaks due to cultural alteration	4
>15 and #30% of riparian reach with gaps / breaks due to cultural alteration	3
>30 and #50% of riparian reach with gaps / breaks due to cultural alteration	2
>50% of riparian reach with gaps / breaks due to cultural alteration	1

Land Use / Land Cover – Riparian Ecosystem Boundary (LULC_{BND} or CA_{BND})

Land Use / Land Cover – Riparian Ecosystem Boundary indicates the presence of cultural features at the boundary of the riparian ecosystem that are likely to inhibit the normal movement of fauna between riparian and adjacent upland habitats. Land use / land cover at the boundary of the riparian ecosystem plays an important role in determining the ability of animals to move freely between riparian and adjacent upland ecosystems on a daily or seasonal basis (Petersen et al. 1992; Vought et al. 1994, Statzner et al. 1997; Vought et al. 1994; Osborne and Kovacic 1993). Under natural conditions, riparian vegetation transitions gradually to native upland vegetation at the edge of the riparian ecosystem. A variety of cultural activities replace these native or naturalized vegetation communities with agriculture, urban/industrial, transportation corridors or other types of LULC that reduce the likelihood the animals can move freely between the riparian ecosystem and adjacent uplands.

This indicator was measured using the ArcView GIS themes of riparian reach and LULC themes, a one-meter wide buffer strip was created at the riparian ecosystem boundary to simulate a boundary condition. The percent of this area occupied by each LULC type was determined, and the LULC types considered to inhibit faunal movement in Table 8 were used to determine the value of the metric.

The reference condition was defined as <5% of the riparian ecosystem boundary composed of LULC types that inhibit faunal movement. Indicator scores were assigned based on the range of indicator values in Table 11.

Table 11. Range of indicator values for scaling the riparian ecosystem boundary indicator

Indicator Value Range	Score
#5% of the riparian boundary inhibits faunal movement	5
>5 and #15% of the riparian boundary inhibits faunal movement	4
>15 and #30% of the riparian boundary inhibits faunal movement	3
>30 and #50% of the riparian boundary inhibits faunal movement	2
>50% of the riparian boundary inhibits faunal movement	1

Land Use / Land Cover - Upland Buffer (LULC_{BUF} or CA_{BUF})

Land Use / Land Cover – Upland Buffer indicates the degree to which the LULC in a buffer zone has been culturally altered. Land Use / Land Cover -Upland Buffer differs from the Land Use / Land Cover - Riparian Reach Boundary indicator in that it is concerned with LULC in the entire adjacent upland landscape and not just at the boundary between the riparian ecosystem and the adjacent upland. Land use / land cover in upland areas adjacent to riparian ecosystems are important because of their ability to support the life requirements of a variety of native species. Under reference conditions the upland buffer consists of native vegetation communities. A variety of cultural activities replace these native or naturalized vegetation communities with agriculture, urban/industrial, transportation corridors or other types of land use. Changes in LULC in the buffer also have the potential to affect the rate at which water and sediment moves toward riparian areas from the uplands (Peterjohn and Correll 1984, 1986; Osborne and Kovacic 1993; Barling and Moore 1994).

This indicator was measured using field observation, aerial photographs, and the ArcView GIS themes of riparian reach and LULC themes. A buffer of 100 m width, or until an adjacent 2nd order or higher watershed boundary was encountered, was established around the riparian reach. The percent of the buffer area occupied by each LULC type was determined, and the LULC types considered to inhibit faunal use in Table 8 were used to determine the value of the indicator.

The reference condition was defined as <5% of the upland buffer with LULC types representing cultural alteration. Indicator scores were assigned based on the range of indicator values in Table 12.

Table 12. Range of indicator values for scaling the riparian ecosystem upland buffer indicator

Metric Value Category	Score
< 5% of the buffer zone with culturally altered LULC types	5
∃5 and #15% of the buffer zone with culturally altered LULC types	4
>15 and #30% of the buffer zone with culturally altered LULC types	3
>30 and #50% of the buffer zone with culturally altered LULC types	2
>50% of the buffer zone with culturally altered LULC types	1

Assessment Procedure (Methods)

The assessment of riparian ecosystem integrity in the San Diego Creek Watershed was conducted by completing the following tasks described in the sections below:

Task 1: Identification of riparian reach assessment units

Task 2: Characterization of riparian reaches

Task 3: Assessment of indicators

Task 4: Assigning indicator scores and calculation of indices

Task 5: Archiving of information

Identification of Riparian Reach Assessment Units

Due to the large size of the project watershed (>450 km^2), inherent variability of riparian ecosystems, and differential nature of historical impacts to riparian ecosystems in the watershed, the initial task was to delineate the riparian areas into relatively homogenous assessment units called “riparian reaches” (Figure 2). A riparian reach (RR) was defined as a segment of the mainstem, bankfull stream channel and the adjacent riparian ecosystem exhibiting relatively homogenous characteristics with respect to geology, geomorphology, channel morphology, substrate type, vegetation communities, and cultural alteration (Olson and Harris 1997).

On non-headwater riparian reaches (i.e., riparian reaches with other riparian reaches upstream) the longitudinal (i.e., upstream / downstream) boundaries of a riparian reach corresponded to changes in stream gradient or channel morphology resulting from geological control (e.g. knick points), tributaries / distributaries, artificial grade control structures, or other features related to cultural alteration. On headwater reaches, the upstream end of mainstem channel of headwater riparian reach always included third order streams (Strahler 1952, 1957) as mapped by Lichvar (2000), and in many cases the upstream end included second order streams. The factors that determined the upstream extent of the riparian reach were stream density, accessibility, and the extent of a riparian vegetation component. Lateral boundaries of each riparian reach corresponded to either an estimate of the 100-year flood elevation contour, the extent of identifiable historic alluvial terraces, or the base of valley wall or artificial structure. In all cases the riparian reach included Riparian Zones 1 and 2 discussed above. Each riparian reach was assigned pneumonic identifier for display and digital manipulation purposes.

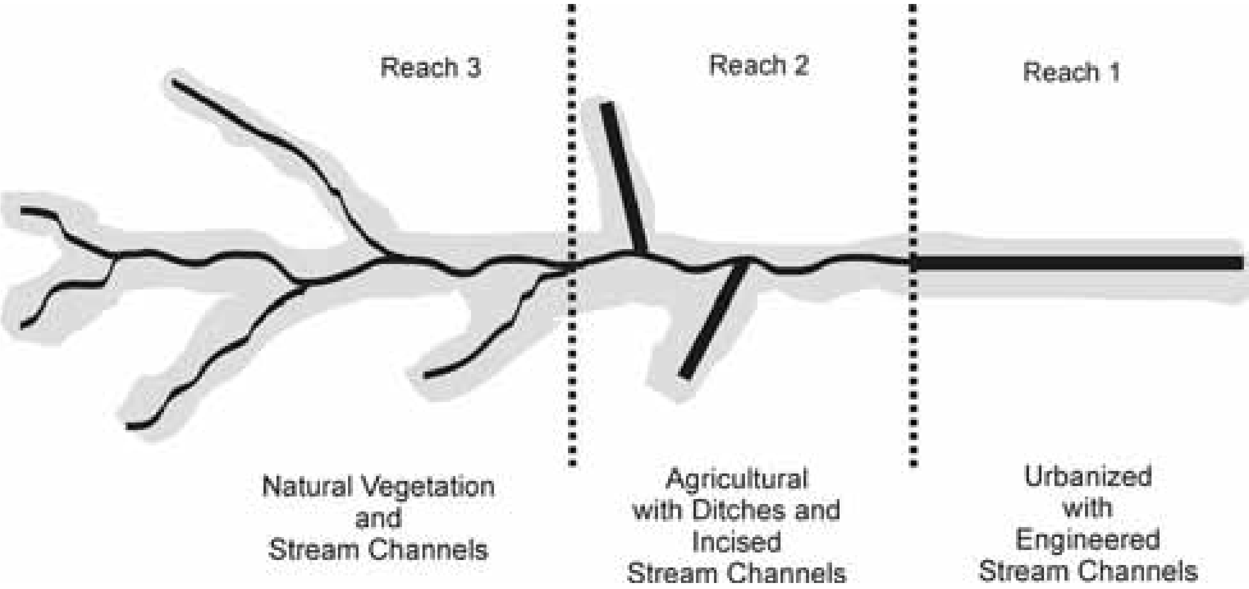

Figure 2. Illustration of the relationship between adjacent riparian reaches

In association with each riparian reach two other areas were defined including a "local drainage area" (LD) and a "drainage basin" (DB). The local drainage area of a riparian reach included the area from which surface water drained directly to the mainstem channel or tributaries that entered the mainstem channel in the riparian reach. The local drainage area did not include areas that drained to the mainstem channel of upstream riparian reaches (Figure 3). The drainage basis of a riparian reach included the local drainage area of a riparian reach in addition to the local drainage area of all upstream riparian reaches (Figure 4).

Preliminary riparian reach, local drainage area, and drainage basin boundaries were mapped on the basis of initial field reconnaissance, aerial photos, and maps. These preliminary boundaries were modified throughout the study based on field visits to each riparian reach, and the WoUS maps developed by Lichvar (2000). Polygons representing the riparian reach, local drainage area, and drainage basin boundaries were constructed in ArcView (see Appendix A).

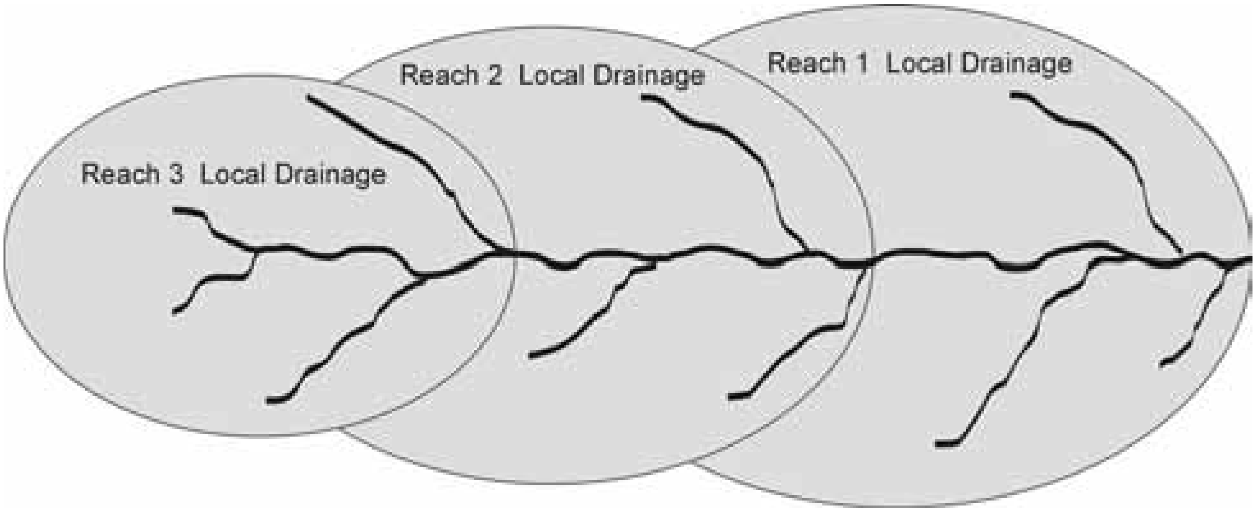

Figure 3. Relationship between riparian reaches and their local drainage

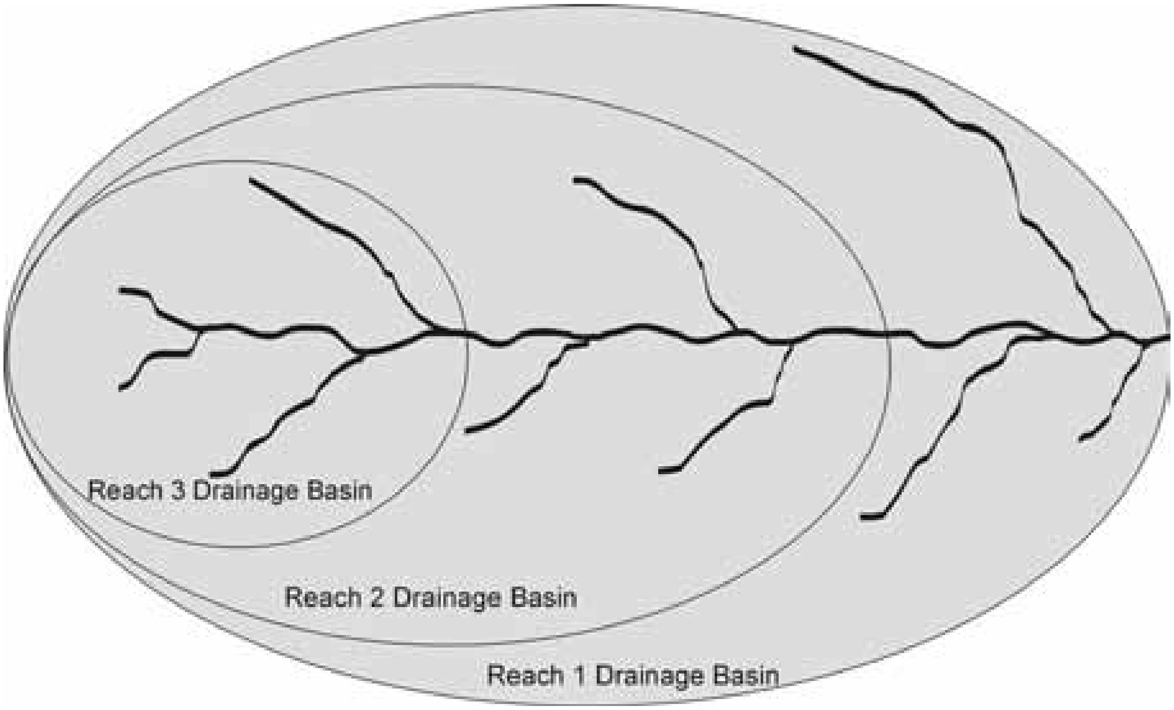

Figure 4. Relationship between riparian reaches and their drainage basins

Characterization of Riparian Reaches

Characterization of riparian reaches was accomplished during a site visit to each reach. Several reaches in the roadless areas such as Upper Borrega Canyon were not visited due to difficult accessibility and time constraints. For these reaches, the characterization was completed to the extent possible using aerial photographs and topographic maps. Table 13 provides a partial listing of the information collected as part of riparian reach characterization. A listing of the all the information collected as part of the characterization effort is provided in Appendix A.

The general strategy during a site visit was to begin at the downstream end of the riparian reach and conduct a walking reconnaissance of the mainstem channel through the riparian reach. On longer reaches we drove to representative sections of the riparian reach and conduct separate walking reconnaissance. On headwater reaches the walking reconnaissance included at least the lower third of the mainstem channel of the riparian reach. Time constraints precluded conducting a walking reconnaissance of the entire mainstem channel of all headwater reaches, and certain roadless areas. In these situations, field observations were supplemented with interpretations based on aerial photographs.

After the reconnaissance walk through a riparian reach, a decision was made to retain the preliminary riparian reach boundaries, or to further divide the riparian reach into two or more riparian reaches. Then, based on the observations made during the walking reconnaissance, a representative portion of the riparian reach was selected and a riparian reach characterization data sheet was completed (Figure 5 and Figure 6). This included notes on the species and location of the dominant vegetation, measurement of channel characteristics, general field notes about the nature of the riparian reach, and indicator values for those integrity indicators measured in the field.

Assessment of Indicators

Indicators were assessed using a combination of fieldwork and spatial analysis in ArcView. Indicators assessed based on field observations included:

- Altered Hydraulic Conveyance – Riparian Reach (AHC_{RR})
- - Perennialized Stream Flow (PSF)

Table 13. Partial listing of characterization and assessment data collected for riparian reaches

Riparian Reach Code	Drainage Basin	USGS 7.5 Minute Topograpic Quad	Mainstem Downstream End Coordinates (UTM)	Mainstem Upstream End Coordinates (UTM)	Size of Mapped Riparian Ecosystem in Riparian Reach Local Drainage (RRLD) (ha)
BG-01	Borrega	El Toro	11S 432113mE 3724084mN	11S 432489mE 3724092mN	0.6
BG-02	Borrega	El Toro	11S 432489mE 3724092mN	11S 434526mE 3725146mN	2.3
BG-03	Borrega	El Toro	11S 434526mE 3725146mN	11S 435220mE 3725638mN	1.9
BG-04a	Borrega	El Toro	11S 435220mE 3725638mN	11S 435820mE 3725995mN	3.7
BG-04b	Borrega	El Toro	11S 435820mE 3725995mN	11S 436169mE 3726065mN	2.5
BG-05a	Borrega	El Toro	11S 436169mE 3726065mN	11S 436890mE 3726895mN	1.1
BG-05b	Borrega	El Toro	11S 436169mE 3726065mN	11S 437227mE 3726661mN	0.0
BG-05c	Borrega	El Toro	11S 436890mE 3726895mN	11S 437348mE 3727084mN	0.8
BG-06	Borrega	El Toro	11S 437361mE 3727089mN	11S 438287mE 3727092mN	0.0
BG-07	Borrega	El Toro	11S 438287mE 3727092mN	11S 439009mE 3728000mN	0.0
BG-08	Borrega	El Toro	11S 439009mE 3728000mN	11S 440726mE 3729049mN	0.0
BG-09	Borrega	El Toro	11S 439009mE 3728000mN	11S 439191mE 3729987mN	0.0
BG-10	Borrega	El Toro	11S 435239mE 3725741mN	11S 435531mE 3726618mN	0.5
BG-11	Borrega	El Toro	11S 435531mE 3726618mN	11S 437156mE 3727433mN	1.2
BG-12	Borrega	El Toro	11S 435531mE 3726618mN	11S 436529mE 3727952mN	0.6
BG-13	Borrega	El Toro	11S 437159mE 3727601mN	11S 437151mE 3728022mN	0.0
BG-14	Borrega	El Toro	11S 436804mE 3727941mN	11S 437134mE 3728122mN	0.0
BG-15	Borrega	El Toro	11S 437482mE 3727771mN	11S 438195mE 3728951mN	0.0
BG-16	Borrega	El Toro	11S 437134mE 3728122mN	11S 438102mE 3729333mN	0.0
BM-01	Bommer	Laguna Beach	11S 426164mE 3722062mN	11S 425230mE 3721572mN	0.6
BM-02a	Bommer	Laguna Beach	11S 425230mE 3721572mN	11S 425486mE 3721023mN	1.1
BM-02b	Bommer	Laguna Beach	11S 424320mE 3720782mN	11S 424251mE 3721545mN	0.0
BM-03	Bommer	Laguna Beach	11S 426097mE 3720505mN	11S 425476mE 3721041mN	0.4
BM-04	Bommer	Laguna Beach	11S 424876mE 3720040mN	11S 425349mE 3721177mN	0.0
BM-05	Bommer	Laguna Beach	11S 425625mE 3720006mN	11S 425476mE 3721041mN	0.9

Table 13. continued

Riparian Reach Code	Size of Mapped Riparian Ecosystem in Riparian Reach Drainage Basin (RRDB) (ha)	Area of RRLD (ha)	Length of RRLD Perimeter (m)	Area of RRDB (ha)	Valley Type (Rosgen)	Valley Length (m)
BG-01	15.2	42	3687	1648	X	373
BG-02	14.6	243	7053	1606	X	2304
BG-03	12.2	130	5163	1363	X	848
BG-04a	8.0	98	5812	811	X	1124
BG-04b	4.3	15	1557	713	X	680
BG-05a	1.9	39	3058	573	VII	1631
BG-05b	0.0	124	5640	124	VII	1229
BG-05c	0.8	20	2228	535	VII	491
BG-06	0.0	45	2741	514	VII	956
BG-07	0.0	132	5413	469	VII	1262
BG-08	0.0	208	7120	208	II	2288
BG-09	0.0	129	5350	129	II	2135
BG-10	2.3	37	2822	422	X	913
BG-11	1.2	92	4918	228	X	1814
BG-12	0.6	70	4625	157	X	1692
BG-13	0.0	29	2428	137	XI	456
BG-14	0.0	22	2158	88	XI	605
BG-15	0.0	108	4629	108	VII / II	1541
BG-16	0.0	66	4219	66	VII / II	1614
BM-01	3.1	156	5994	657	VII	1045
BM-02a	0.9	50	3343	371	VII	624
BM-02b	3.9	44	2977	748	VII / II	1005
BM-03	0.5	35	2834	85	II	834
BM-04	0.0	49	3357	49	II	1269
BM-05	0.9	63	4216	202	VII	1399

Table 13. continued

Riparian Reach Code	Valley Width (m)	Mainstem Downstream End Elevation (m)	Mainstem Upstream End Elevation (m)	Valley Slope (%) (Estimated From 7.5 Minute Topo)	Engineered Channel Type or Rosgen Stream Type
BG-01	no data	74	84	2.7	Engineered - Earthen and Riprap
BG-02	no data	93	122	1.3	Engineered - Concrete
BG-03	no data	133	151	2.1	D
BG-04a	no data	151	169	1.6	D
BG-04b	no data	169	176	1.0	D
BG-05a	372	176	203	1.7	G
BG-05b	372	176	210	2.8	Engineered - Earthen
BG-05c	310	203	210	1.4	Engineered - Concrete and Earthen
BG-06	320	212	243	3.2	Engineered "Restored"
BG-07	110	243	281	3.0	C and D
BG-08	30	281	422	6.2	A and B
BG-09	25	281	452	8.0	A and B
BG-10	no data	155	167	1.3	C, D, and G
BG-11	no data	167	223	3.1	B, C, and G
BG-12	no data	167	219	3.1	B, C, and G
BG-13	no data	229	249	4.4	Engineered - Earthen
BG-14	no data	230	248	3.0	G and Engineered - Earthen
BG-15	45	245	441	12.7	A and B
BG-16	44	258	430	10.7	A and B
BM-01	375	68	86	1.7	C and Engineered - Underground
BM-02a	200	86	100	2.2	C and B
BM-02b	30	105	188	8.3	A and B
BM-03	60	95	156	7.3	B and G
BM-04	10	96	269	13.6	A and B
BM-05	160	134	156	1.6	B, C, and G

Table 13. continued

Riparian Reach Code	Mainstem Channel Length in RRLD (m) (Smith)	Mainstem Channel Length in RRDB (m) (Smith)	Mainstem and Tributary Channel Length in RRLD (m) (Lichvar)	Mainstem and Tributary Channel Length in RRDB (m) (Lichvar)	Mainstem Channel Length / Mainstem Channel and Tributary Channels Length	Drainage Density (Calculated)
BG-01	764	24844	395	63343	0.5	9
BG-02	2418	24080	2766	62949	1.1	11
BG-03	882	21662	1471	60182	1.7	11
BG-04a	805	11082	1990	38198	2.5	20
BG-04b	398	10277	395	36208	1.0	26
BG-05a	1118	9382	1131	34475	1.0	29
BG-05b	497	497	1338	1338	2.7	11
BG-05c	1283	8264	475	33343	0.4	23
BG-06	1081	6981	780	32868	0.7	17
BG-07	1342	5900	1533	32088	1.1	12
BG-08	2468	2468	20168	20168	8.2	97
BG-09	2090	2090	10386	10386	5.0	80
BG-10	962	9698	948	20514	1.0	26
BG-11	2426	4570	3171	12218	1.3	35
BG-12	1927	4166	1916	7348	1.0	28
BG-13	427	2144	641	9046	1.5	22
BG-14	580	2239	621	5432	1.1	28
BG-15	1717	1717	8405	8405	4.9	78
BG-16	1659	1659	4811	4811	2.9	73
BM-01	1279	10567	1392	27745	1.1	9
BM-02a	525	6682	2066	21061	3.9	41
BM-02b	1046	10865	1668	39215	1.6	38
BM-03	1035	2434	1558	4409	1.5	45
BM-04	1302	1302	3723	3723	2.9	76
BM-05	1195	3504	2997	10307	2.5	47

Table 13. continued

Riparian Reach Code	Channel Slope % (Calculated)	Sinuosity (Calculated)	Bankfull Width (ft)	Bankfull Width (m)	Floodprone Width (ft)	Floodprone Width (m)
BG-01	1.3	0.5	20.0	6.1	45.0	13.7
BG-02	1.2	1.0	no data	no data	no data	no data
BG-03	2.0	1.0	13.0	4.0	25.0	7.6
BG-04a	2.2	1.4	no data	no data	no data	no data
BG-04b	1.8	1.7	28.0	8.5	80.0	24.4
BG-05a	2.4	1.5	21.0	6.4	50.0	15.2
BG-05b	6.8	2.5	no data	no data	no data	no data
BG-05c	0.5	0.4	no data	no data	no data	no data
BG-06	2.9	0.9	no data	no data	no data	no data
BG-07	2.8	0.9	7.0	2.1	25.0	7.6
BG-08	5.7	0.9	10.0	3.0	15.0	4.6
BG-09	8.2	1.0	3.0	0.9	5.0	1.5
BG-10	1.2	0.9	10.0	3.0	25.0	7.6
BG-11	2.3	0.7	9.0	2.7	15.0	4.6
BG-12	2.7	0.9	2.0	0.6	6.0	1.8
BG-13	4.7	1.1	no data	no data	no data	no data
BG-14	3.1	1.0	no data	no data	no data	no data
BG-15	11.4	0.9	1.5	0.5	5.0	1.5
BG-16	10.4	1.0	3.0	0.9	6.0	1.8
BM-01	1.4	0.8	no data	no data	no data	no data
BM-02a	2.7	1.2	10.0	3.0	13.0	4.0
BM-02b	7.9	1.0	3.5	1.1	7.0	2.1
BM-03	5.9	0.8	10.0	3.0	13.0	4.0
BM-04	13.3	1.0	3.0	0.9	6.0	1.8
BM-05	1.8	1.2	15.0	4.6	18.0	5.5

Table 13. continued

Riparian Reach Code	Bankfull Maximum Depth (in)	Bankfull Maximum Depth (cm)	Bankfull Mean Depth (in)	Bankfull Mean Depth (cm)	Bankfull Cross-Sectional Area (m^2)	Width / Depth Ratio (Calculated)
BG-01	14.0	35.6	10.0	25.4	1.5	0.2
BG-02	no data	no data	no data	no data	no data	no data
BG-03	16.0	40.6	14.0	35.6	1.4	0.1
BG-04a	no data	no data	no data	no data	no data	no data
BG-04b	18.0	45.7	14.0	35.6	3.0	0.2
BG-05a	20.0	50.8	15.0	38.1	2.4	0.2
BG-05b	no data	no data	no data	no data	no data	no data
BG-05c	no data	no data	no data	no data	no data	no data
BG-06	no data	no data	no data	no data	no data	no data
BG-07	12.0	30.5	6.0	15.2	0.3	0.1
BG-08	5.0	12.7	4.5	11.4	0.3	0.3
BG-09	6.0	15.2	4.0	10.2	0.1	0.1
BG-10	7.0	17.8	6.0	15.2	0.5	0.2
BG-11	8.0	20.3	7.0	17.8	0.5	0.2
BG-12	3.0	7.6	2.0	5.1	0.0	0.1
BG-13	no data	no data	no data	no data	no data	no data
BG-14	no data	no data	no data	no data	no data	no data
BG-15	6.0	15.2	6.0	15.2	0.1	0.0
BG-16	7.0	17.8	5.0	12.7	0.1	0.1
BM-01	no data	no data	no data	no data	no data	no data
BM-02a	14.0	35.6	12.0	30.5	0.9	0.1
BM-02b	5.0	12.7	4.0	10.2	0.1	0.1
BM-03	12.0	30.5	8.0	20.3	0.6	0.2
BM-04	6.0	15.2	5.0	12.7	0.1	0.1
BM-05	18.0	45.7	16.0	40.6	1.9	0.1

Table 13. continued

Riparian Reach Code	Entrenchment Ratio (Calculated)	Natural Channel Substrate Bedrock / Boulder (%)	Natural Channel Substrate Cobble (%)	Natural Channel Substrate Gravel (%)	Natural Channel Substrate Sand (%)	Natural Channel Substrate Silt / Clay (%)
BG-01	2.3	0	5	10	80	5
BG-02	no data	no data	no data	no data	no data	no data
BG-03	1.9	0	5	10	80	5
BG-04a	no data	0	5	5	90	0
BG-04b	2.9	0	20	10	70	0
BG-05a	2.4	0	20	20	50	10
BG-05b	no data	no data	no data	no data	no data	no data
BG-05c	no data	no data	no data	no data	no data	no data
BG-06	no data	no data	no data	no data	no data	no data
BG-07	3.6	0	10	20	50	20
BG-08	1.5	5	15	20	60	0
BG-09	1.7	5	10	5	5	75
BG-10	2.5	0	10	10	70	10
BG-11	1.7	0	20	20	50	10
BG-12	3.0	0	0	10	60	30
BG-13	no data	no data	no data	no data	no data	no data
BG-14	no data	no data	no data	no data	no data	no data
BG-15	3.3	0	30	20	20	30
BG-16	2.0	0	10	10	70	10
BM-01	no data	no data	no data	no data	no data	no data
BM-02a	1.3	0	0	0	20	80
BM-02b	2.0	10	10	10	30	40
BM-03	1.3	0	0	10	30	60
BM-04	2.0	0	0	10	30	60
BM-05	1.2	10	30	10	30	20

Table 13. continued

Riparian Reach Code	Indicator 1 % of Channel in RRLD with Altered Hydraulic Conveyance (field observation)	Indicator 2 % of Channel in RRDB with Altered Hydraulic Conveyance (GIS)	Indicator 3 % of Area with Native Riparian Vegetation (field observation)	Indicator 4 % of Floodplain Present and not Isolated from Channel (field observation)	Indicator 5 % of Channel with Perennialized Stream Flow (field observation)
BG-01	100	36	50	50	100
BG-02	100	34	0	0	100
BG-03	80	27	80	60	0
BG-04a	10	37	100	100	0
BG-04b	10	39	100	100	0
BG-05a	100	37	50	25	0
BG-05b	100	100	0	0	100
BG-05c	100	29	0	100	100
BG-06	100	15	0	0	0
BG-07	0	0	100	100	100
BG-08	0	0	100	100	0
BG-09	0	0	100	100	100
BG-10	0	10	75	50	0
BG-11	0	9	100	50	0
BG-12	0	14	100	100	0
BG-13	100	20	0	0	0
BG-14	100	26	50	25	0
BG-15	0	0	100	100	0
BG-16	0	0	100	100	0
BM-01	50	6	25	50	50
BM-02a	0	0	90	100	0
BM-02b	0	23	25	100	0
BM-03	0	0	100	100	0
BM-04	0	0	80	80	0
BM-05	0	0	100	100	0

Table 13. continued

Riparian Reach Code	Indicator 6 % of Flood Prone Area in the RRLD with Riparian Corridor Breaks (field observation)	Indicator 7 % of Channel in the RRDB with Riparian Corridor Breaks (field observation)	Indicator 8 % of Channel in RRLD with Culturally Altered Buffer (100 m) (field observation)	Indicator 9 Sediment Regime Condition Index of Channel in RRLD (field observation)	Indicator 10 % of RRDB from which Surface Water is Imported, Exported or Diverted Water (GIS)	Indicator 11 % of LULC with the Potential to Contribute to a Nutrient Increase in Surface Waters (GIS)
BG-01	75	30	100	1	0	97
BG-02	100	29	100	1	0	97
BG-03	20	21	100	2	0	96
BG-04a	0	26	70	2	0	93
BG-04b	0	28	50	2	0	93
BG-05a	100	26	100	2	0	91
BG-05b	100	100	100	1	0	99
BG-05c	100	16	100	1	0	91
BG-06	0	0	100	1	0	93
BG-07	0	0	10	3	0	93
BG-08	0	0	10	4	0	86
BG-09	0	0	0	4	0	98
BG-10	25	15	100	2	0	100
BG-11	0	9	100	2	0	100
BG-12	25	19	100	3	0	100
BG-13	100	20	100	1	0	100
BG-14	50	13	100	1	0	100
BG-15	0	0	0	4	0	100
BG-16	0	0	0	4	0	100
BM-01	75	19	100	2	0	100
BM-02a	10	4	100	3	0	100
BM-02b	75	28	100	2	0	83
BM-03	0	0	100	2	0	100
BM-04	20	20	50	3	0	100
BM-05	0	0	75	3	0	100

Table 13. continued

Riparian Reach Code	Indicator 12 % of LULC with the Potential to Contribute to a Pesticide Increase in Surface Waters (GIS)	Indicator 13 % of LULC with the Potential to Contribute to a Hydrocarbon Increase in Surface Waters (GIS)	Indicator 14 % of LULC with the Potential to Contribute to a Sediment Increase in Surface Waters (GIS)	Indicator 15 % of RRLD with a Culturally Altered Boundary (GIS)	Indicator 16 % of RRDB affected by Surface Water Retention in Reservoirs and Detention Basins (GIS)
BG-01	97	17	90	100	0
BG-02	97	16	90	100	0
BG-03	96	11	96	100	0
BG-04a	93	9	93	100	0
BG-04b	93	7	93	100	0
BG-05a	91	7	91	72	0
BG-05b	99	0	99	0	0
BG-05c	91	4	91	100	0
BG-06	93	4	93	5	0
BG-07	93	5	93	0	0
BG-08	86	11	86	0	0
BG-09	98	0	98	0	0
BG-10	100	16	100	100	0
BG-11	100	25	100	69	0
BG-12	100	2	100	31	0
BG-13	100	0	100	100	0
BG-14	100	0	100	0	0
BG-15	100	0	100	0	0
BG-16	100	0	100	0	0
BM-01	100	4	96	63	0
BM-02a	100	0	100	100	0
BM-02b	83	6	83	100	0
BM-03	100	0	100	100	0
BM-04	100	0	100	100	0
BM-05	100	0	100	100	0

Table 13. continued

Riparian Reach Code	Indicator 1 Score % of Channel in RRLD with Altered Hydraulic Conveyance (field observation)	Indicator 2 Score % of Channel in RRDB with Altered Hydraulic Conveyance (GIS)	Indicator 3 Score % of Flood Prone Area with Riparian Vegetation (field observation)	Indicator 4 Score % of Floodplain Present and not Isolated from Channel (field observation)	Indicator 5 Score % of Channel with Perennialized Stream Flow (field observation)
BG-01	1	2	2	2	1
BG-02	1	2	1	1	1
BG-03	1	3	3	2	5
BG-04a	4	2	5	5	5
BG-04b	4	2	5	5	5
BG-05a	1	2	2	1	5
BG-05b	1	1	1	1	1
BG-05c	1	3	1	5	1
BG-06	1	3	1	1	5
BG-07	5	5	5	5	1
BG-08	5	5	5	5	5
BG-09	5	5	5	5	1
BG-10	5	4	3	2	5
BG-11	5	4	5	2	5
BG-12	5	4	5	5	5
BG-13	1	3	1	1	5
BG-14	1	3	2	1	5
BG-15	5	5	5	5	5
BG-16	5	5	5	5	5
BM-01	2	4	1	2	2
BM-02a	5	5	4	5	5
BM-02b	5	3	1	5	5
BM-03	5	5	5	5	5
BM-04	5	5	3	3	5
BM-05	5	5	5	5	5

Table 13. continued

Riparian Reach Code	Indicator 6 Score % of Flood Prone Area in the RRLD with Riparian Corridor Breaks (field observation)	Indicator 7 Score % of Channel in the RRDB with Riparian Corridor Breaks (field observation)	Indicator 8 Score % of Channel in RRLD with Culturally Altered Buffer (100 m) (field observation)	Indicator 9 Score Sediment Regime Condition Index of Channel in RRLD (field observation)	Indicator 10 Score % of RRDB from which Surface Water is Imported, Exported or Diverted Water (GIS)	Indicator 11 Score % of LULC with the Potential to Contribute to a Nutrient Increase in Surface Waters (GIS)
BG-01	1	2	1	1	5	1
BG-02	1	3	1	1	5	1
BG-03	3	3	1	2	5	1
BG-04a	5	3	1	2	5	1
BG-04b	5	3	2	2	5	1
BG-05a	1	3	1	2	5	1
BG-05b	1	1	1	1	5	1
BG-05c	1	3	1	1	5	1
BG-06	5	5	1	1	5	1
BG-07	5	5	4	3	5	1
BG-08	5	5	4	4	5	1
BG-09	5	5	5	4	5	1
BG-10	3	4	1	2	5	1
BG-11	5	4	1	2	5	1
BG-12	3	3	1	3	5	1
BG-13	1	3	1	1	5	1
BG-14	2	4	1	1	5	1
BG-15	5	5	5	4	5	1
BG-16	5	5	5	4	5	1
BM-01	1	3	1	2	5	1
BM-02a	4	5	1	3	5	1
BM-02b	1	3	1	2	5	1
BM-03	5	5	1	2	5	1
BM-04	3	3	2	3	5	1
BM-05	5	5	1	3	5	1

Table 13. continued

Riparian Reach Code	Indicator 12 Score % of LULC with the Potential to Contribute to a Pesticide Increase in Surface Waters (GIS)	Indicator 13 Score % of LULC with the Potential to Contribute to a Hydrocarbon Increase in Surface Waters (GIS)	Indicator 14 Score % of LULC with the Potential to Contribute to a Sediment Increase in Surface Waters (GIS)	Indicator 15 Score % of RRLD with a Culturally Altered Boundary (GIS)	Indicator 16 Score % of RRDB affected by Surface Water Retention in Reservoirs and Detention Basins (GIS)
BG-01	1	3	1	1	1
BG-02	1	3	1	1	1
BG-03	1	4	1	1	1
BG-04a	1	4	1	1	1
BG-04b	1	4	1	1	1
BG-05a	1	4	1	1	1
BG-05b	1	5	1	5	1
BG-05c	1	5	1	1	1
BG-06	1	5	1	5	1
BG-07	1	5	1	5	1
BG-08	1	4	1	5	1
BG-09	1	5	1	5	1
BG-10	1	3	1	1	1
BG-11	1	3	1	1	1
BG-12	1	5	1	2	1
BG-13	1	5	1	1	1
BG-14	1	5	1	5	1
BG-15	1	5	1	5	1
BG-16	1	5	1	5	1
BM-01	1	5	1	1	1
BM-02a	1	5	1	1	1
BM-02b	1	4	1	1	1
BM-03	1	5	1	1	1
BM-04	1	5	1	1	1
BM-05	1	5	1	1	1

Table 13. completed

Riparian Reach Code	Sum of Hydrologic Indicator Scores (possible 30)	Sum of Water Quality Indicator Scores (possible 45)	Sum of Habitat Indicator Scores (possible 30)	Sum of all Indicator Scores (possible 80)
BG-01	8	17	7	26
BG-02	7	15	7	25
BG-03	14	24	11	37
BG-04a	19	31	15	46
BG-04b	19	31	16	47
BG-05a	12	21	8	32
BG-05b	6	14	9	28
BG-05c	12	20	7	32
BG-06	12	20	17	42
BG-07	20	32	24	57
BG-08	25	37	24	61
BG-09	21	33	25	59
BG-10	19	29	12	42
BG-11	19	31	16	46
BG-12	23	35	14	50
BG-13	12	20	7	32
BG-14	12	21	14	39
BG-15	25	37	25	63
BG-16	25	37	25	63
BM-01	13	21	7	33
BM-02a	24	35	15	52
BM-02b	21	29	7	40
BM-03	23	35	17	53
BM-04	22	32	12	47
BM-05	24	36	17	54

- Area of Native Riparian Vegetation (NRV)
- Riparian Corridor Continuity – Riparian Reach (RCC_{RR})
- Floodplain Interaction (FI)
- Sediment Regime (SR)

Indicators measured using ArcView GIS included:

- Altered Hydraulic Conveyance – Drainage Basin (AHC_{DB})
- Riparian Corridor Continuity – Watershed (RCC_{DB})
- Surface Water Retention (SWR)
- Import, Export, or Diversion of Surface Water (IED)
- Land Use / Land Cover – Nutrient Increase ($LULC_N$)
- Land Use / Land Cover – Pesticide Increase ($LULC_P$)
- Land Use / Land Cover – Hydrocarbon Increase ($LULC_H$)
- Land Use / Land Cover – Sediment Increase ($LULC_S$)
- Land Use / Land Cover - Riparian Reach Boundary ($LULC_{BND}$ or CA_{BND})
- Land Use / Land Cover - Upland Buffer ($LULC_{BUF}$ or CA_{BUF})

Information on the specific procedure used to measure each indicator is given in the Assessment Indicators section above.

Based on field observation and/or spatial analysis each indicator was assigned a value representing the percent deviation of the indicator from the reference condition in that reach. For example, if the mainstem of a riparian reach was completely channelized, an indicator value of 100 was assigned to the Altered Hydraulic Conveyance – Riparian Reach indicator. The assignment of values to indicators was based on an assumed, relative, categorical relationship defined between indicators and assessment endpoints. The assumption was that an increase in the deviation from the reference condition represented an equivalent decrease in the level of riparian ecosystem integrity in terms of the specific indicator. For example, in comparing two riparian reaches in terms of the land use / land cover indicator, the riparian reach with the larger percentage of urban land use / land cover in the drainage basin would be assumed to have lower integrity, at least in terms of the contribution of the indicator to endpoint integrity. This approach to scaling indicators to reference condition, and by implication to endpoint integrity, was possible because of the way indicators were defined (i.e., always measurable as a percent deviation from reference condition), and based on information from published studies, field data and observations, professional judgment, common sense as outlined the Assessment Endpoints and Assessment Indicators sections above.

Assigning Indicator Scores and Calculation of Indices

To simplify the calculation of endpoint indices, and facilitate presentation of results in tables, charts, and ArcView, indicator values were converted into scores. The range of indicator values (i.e., percent deviation from reference condition 0-100) was divided into five categories and assigned an indicator score of 1-5 (see Tables 1-12). A score of 5 represented close concurrence with the reference condition, and consequently a high level of integrity. A score of 1 represented a deviation of 50% or more the reference condition, and consequently a low level of integrity.

Initial category ranges for indicator values were based on the natural groupings of the data collected during the project, and the subjective integration of numerous field observations relating indicator values to endpoint integrity. Testing of other category ranges (i.e., correlation analysis using quartiles and quintiles) showed no significant change in the relationship between riparian reaches in terms of either indicator scores or endpoint indices. Thus, initial category ranges were retained.

Hydrologic, water quality, and habitat integrity indices were calculated in the spreadsheet by summing the scores of the indicators associated with hydrologic, water quality, and habitat integrity as discussed above. Individual indicator scores and summary indices were presented in tabular form in the spreadsheet and spatially in ArcView.

Archiving of Information

All of the information and data collected during the characterization and assessment of riparian reaches (discussed above), as well as results derived from this information (discussed below), were archived in an Excel spreadsheet, ArcView project file, and an Access database format. Appendices A, B, and C discuss the archiving of this information, data, and results in each of these formats respectively.

Riparian Reach Characterization Form – San Diego Creek

Reach Identifier ________ Aerial Photo Line / No. ______________________________	Field Notes and Comments
Date: ____ / _____ / 1999 Field Crew _____________________________________	
UTM Coord. Downstream End 11S - _______________ mE __________________ mN	
UTM Coord. Upstream End 11S - _________________ mE __________________ mN	
7.5 Minute Quad Name _________________ T: R: S: Q:	
Reach Drainage Basin Area ___________ ha	
Valley Type: I II III IV V VI VII VIII IX X XI	
Valley Slope ____ % Valley Length ______ m / ft Valley Width ______ m / ft	
Stream Type Aa+ A B C D Da E F G 1 2 3 4 5 6	
Channel Slope ____ % Channel Length _____ % Sinuosity: _____ (valley/channel)	
BKF Width (Wbkf) _______ m / ft Floodprone Width (Wfpa) _______ m / ft	
BKF Max Depth (dmax) _____ m / ft / in BKF Mean Depth (dbkf) _____ m / ft / in	
Width / Depth Ratio _______ (Wbkf / dbkf) Entrenchment Ratio ______ (Wfpa / Wbkf)	
Channel Substrate (%) Boulder _____ Cob _____ Gra _____ Snd _____ Slt/Cla _____	
AHC: % of reach with altered hydraulic conveyance _____	
ARV: % of flood prone area occupied by native riparian vegetation _____	
FI: % of floodplain isolated from overbank flow on right bank _____ and left bank _____	
PSF: % of reach with perennialized flow _____	
RCCR: % of flood prone area with corridor breaks _____	
RRB: % if reach bounded laterally by culturally altered features _____	
SR: sediment regime descriptive index code _____	

Particle Size Classes: Boulder-large = 20+ in. Boulder-small = 10-20 in. Cobble = 2.5-10 in. Gravel = 0.08-2.5 in. Sand = 0.062-2 ml Silt/Clay = <0.062 ml

Figure 5. Data sheet side 1

Vegetation (Codes: D=dominant=common P=present C=Channel F=Floodplain S=sideslope T=terrace

Trees

_____ Populus trichocarpa
_____ Quercus agrifolia
_____ Quercus dumosa
_____ Salix goodingii
_____ Salix exegua
_____ Salix laevigata
_____ Salix laseolepis

Herbs

_____ Urtica dioica

Vines

_____ Vitis girdiana

Shrubs

_____ Artemisia californica
_____ Artemesia douglasiana
_____ Amorpha fruticosa
_____ Baccharis salicifolia
_____ Baccharis sarothroides
_____ Eriogonum fasciculatum
_____ Hazardia squarrosa
_____ Isocoma veneta
_____ Lepidospartum squam…
_____ Malosma laurina
_____ Toxicodendron radicans

Emergent Aquatics

_____ Cyperus eragrostis
_____ Juncus balticus
_____ Persicaria lapathifolium
_____ Persicaria punctata
_____ Rumex spp.
_____ Scirpus americana
_____ Scirpus californicus
_____ Scirpus robustus
_____ Typha latifolia
_____ Typha domingensis

Exotics

_____ Arundo donax
_____ Brassica sylvestris
_____ Eucalyptus spp.
_____ Foeniculum vulgare
_____ Melilotus albus
_____ Melilotus officianalis
_____ Nicotiana glauca
_____ Schinus terebinthifolius
_____ Tamarix parvifolia
_____ Xanthium strumariam

Other

_____
_____
_____
_____
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_____

Drawings / Cross Sections

Figure 6. Data sheet side 2

Results and Discussion

One hundred and eighty six riparian reaches were identified in the San Diego Creek Watershed. The size of the riparian reach local drainages ranged from 3 to 2931 hectares with a mean of 164 hectares, and the size of riparian reach drainage basins ranged from 25 to 31632 hectares with a mean of 1285 hectares. The length of the mainstem channels through the riparian reach ranged from 141 to 1130 meters with a mean of 1504 meters. The wide ranges in these characteristics primarily reflect the extreme difference in the size of riparian reaches identified in hetreogenous urban versus more homogenous natural landscapes. The minimum, maximum, and mean of indicator values, and the frequency of indicator scores for all riparian reaches is summarized in Table 14.

The range of values for the endpoint indices (i.e., sum of relevant indicator scores) for hydrologic integrity was 6 - 29 with a mean of 18 out of a possible 30, for water quality integrity was 13 - 42 with a mean of 28 out of a possible 45, and for habitat intergrity was 5 - 25 with a mean of 12 out of a possible 30. Figure 7 shows the distribution of endpoint indices across all riparian reaches. In general the index values exhibited a relatively wide and even spread across the possible range of index values. These results can be interpreted as evidence that the indicators were scaled appropriately, and sensitive enough to distinguish varying degrees of hydrologic, water quality, and habitat integrity. This is encouraging given that the results fit our perception of riparian ecosystem integrity in the watershed based on extensive field work and observations. Ultimately, however, the only way to increase confidence in the integrity indices is through testing an verification with more quantitative models of hydrologic, water quality, and habitat integrity.

Because of the extensive amount of data collected for each riparian reach and the inherently spatial nature of the data, the Excel spreadsheet and ArcView project file are much better formats for reviewing the results in terms of the three tasks required to meet the project objective (see Project Objective section above). Consequently, the objective here will be to provide examples and illustrations to acquaint readers with the way in which results can be presented and summarized in the database, spreadsheet, and ArcView formats.

Table 14. Descriptive statistics for indicator values and indicator scores

Indicator	Min Value	Max Value	Mean Value	Frequency				
				Score 5	Score 4	Score 3	Score 2	Score 1
AHC$_{RR}$	0	100	54	79	2	4	2	100
AHC$_{DB}$	0	100	39	64	16	21	13	73
NRV	0	100	53	74	6	15	11	81
FI	0	100	54	88	2	3	14	80
PSF	0	100	38	110	1	1	8	67
RCC$_{RR}$	0	100	52	59	10	19	8	91
RCC$_{DB}$	0	100	41	43	19	33	16	76
LULC$_{BUF}$	0	100	78	10	7	16	17	137
SR	NA	NA	NA	111	64	86	37	62
IED	0	0	0	187	0	0	0	0
LULC$_{N}$	16	100	94	0	0	1	3	183
LULC$_{P}$	16	100	94	0	0	1	3	183
LULC$_{H}$	0	100	15	94	33	24	18	18
LULC$_{S}$	0	100	84	2	2	5	6	172
LULC$_{BND}$	0	100	70	42	1	5	9	130
SWR	0	100	19	130	3	13	5	36

Figures 8 and 9 illustrate the summary report available for each riparian reach in the database (see Appendix C). This summary report is an ideal starting point for reviewing results because it provides a good overview of a riparian reach in terms of its characteristics and indicator scores.

Figure 10 is an ArcView layout showing the location of riparian reaches in the San Diego Creek Watershed. Each polygon in the figure represents the local drainage of a riparian reach. Labels are the codes assigned to each riparian reach and used to identify riparian reaches in the spreadsheet, ArcView project, and database.

Figure 11 is another ArcView layout showing a portion of the San Diego Creek Watershed in the vicinity of Borrego and Serrano Creeks. In the figure, brown polygons again represent the local drainage of a riparian reach. The riparian ecosystem in each reach consists of blue lines and colored polygons representing wetland ratings from Lichvar (2000). This type of display can be quickly presented for any portion of the San Diego Creek Watershed in ArcView. Attachment 1 is a fold-up map that shows this same view for the entire San Diego Creek Watershed.

Figure 12 is a bar chart showing indictor scores for each of the riparian reaches in the Borrego Canyon drainage basin. This type of bar chart can be quickly displayed in ArcView as a hotlinked image, in the spreadsheet and database as a hyperlink.

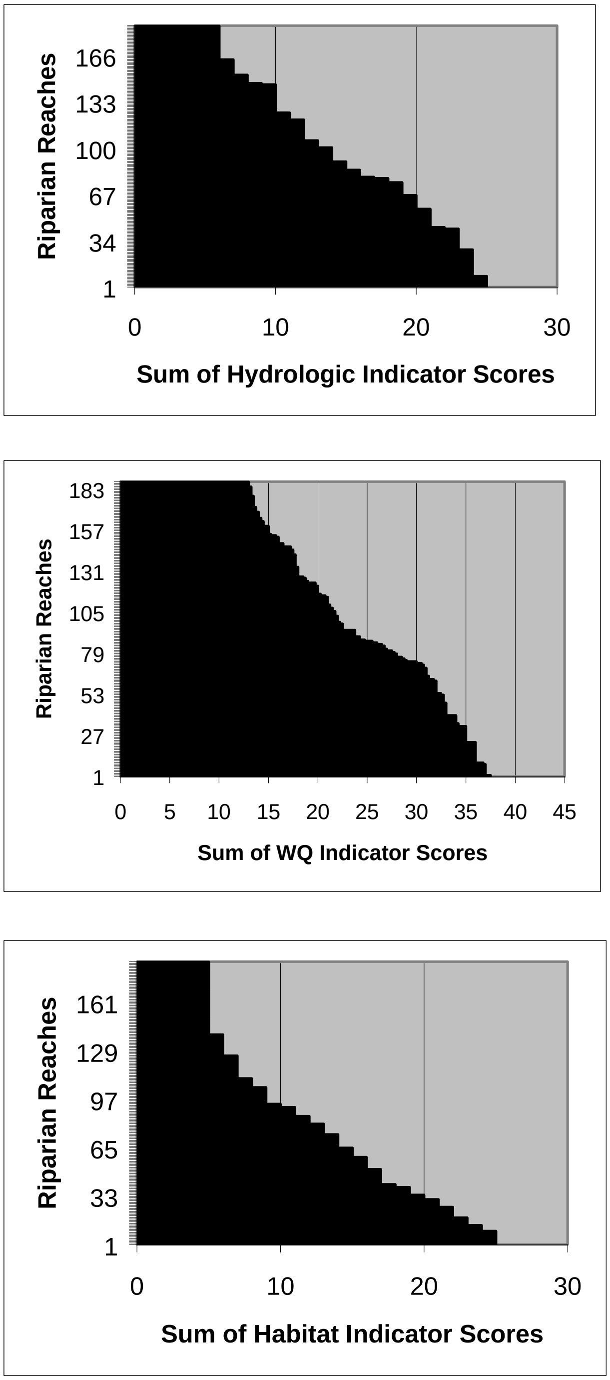

Figure 7. Index values for hydrologic, water quality, and habitat integrity for all riparian reaches

San Diego Creek Watershed

Riparian Reach Characterization and Functional Assessment Summary

General Information

Drainage Basin: Aqua Chinon
Riparian Reach ID: AC-05
USGS 7.5 Minute Topo: El Toro
UTM Coordinates Downstream End:
11S 434762mE 3727275mN
UTM Coordinates Upstream End:
11S 435088mE 3727338mN
Size of Riparian Reach: 32.8 ha
Size of Drainage Basin: 700 ha
Area of Riparian Ecosystem: 1 ha

Channel Characteristics

Channel Type or Rosgen Stream Type if Natural Channel: C and D
Length of Mainstem Channel Through Reach: 1000 m
Channel Substrates (Natural Channels Only):
    % Bedrock or Boulder: 0
    % Cobble: 10
    % Gravel: 20
    % Sand: 60
    % Silt / Clay: 10
Channel Geometry in Representative Section of Lower Portion of Reach:
    Bankfull Width: 4.6 m
    Flood Prone Width: 5.8 m
    Mean Bankfull Depth: 38.1
    Bankfull Cross-Sectional Area: 1.7 m^2

Indicators of Functional Integrity

% of Reach with Altered Hydraulic Conveyance: 0
% of Drainage Basin with Altered Hydraulic Conveyance: 16
% of Floodplain Removed or Isolated from Channel: 0
% of Channel with Perennial Flow Due to Supplementary Sources: 0
Sediment Regime Condition Index: 2
% of Drainage Basin Surface Water Imported, Exported, or Diverted: 0
% of Drainage Basin affected by Surface Water Storage Structures: 93
% of Drainage Basin with Land Uses that increase surface water nutrients: 93
% of Drainage Basin with Land Uses that increase surface water pesticides: 93

Figure 8. Page 1 of an example of database summary report

% of Drainage Basin with Land Uses that increase surface water hydrocarbons: 93
% of Drainage Basin with Land Uses that increase surface water sediments: 93
% of Flood Prone Area in Reach Functioning as Corridor Breaks: 0
% of Flood Prone Area in Drainage Basin Functioning as Corridor Breaks: 0
% of Riparian Ecosystem Boundary with Culturally Altered Land Uses: 100
% of Riparian Ecosystem Buffer (100 m) with Culturally Altered Land Uses: 100
% of Flood Prone Area supporting Native Riparian Vegetation: 100

Indicator Scores

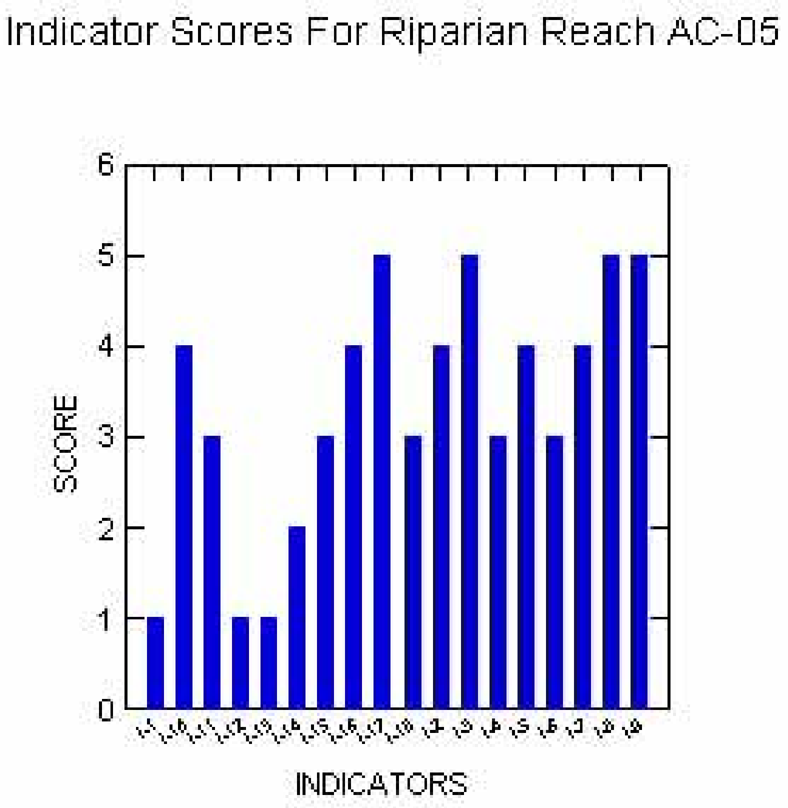

Figure 9. Page 2 of an example of database summary report

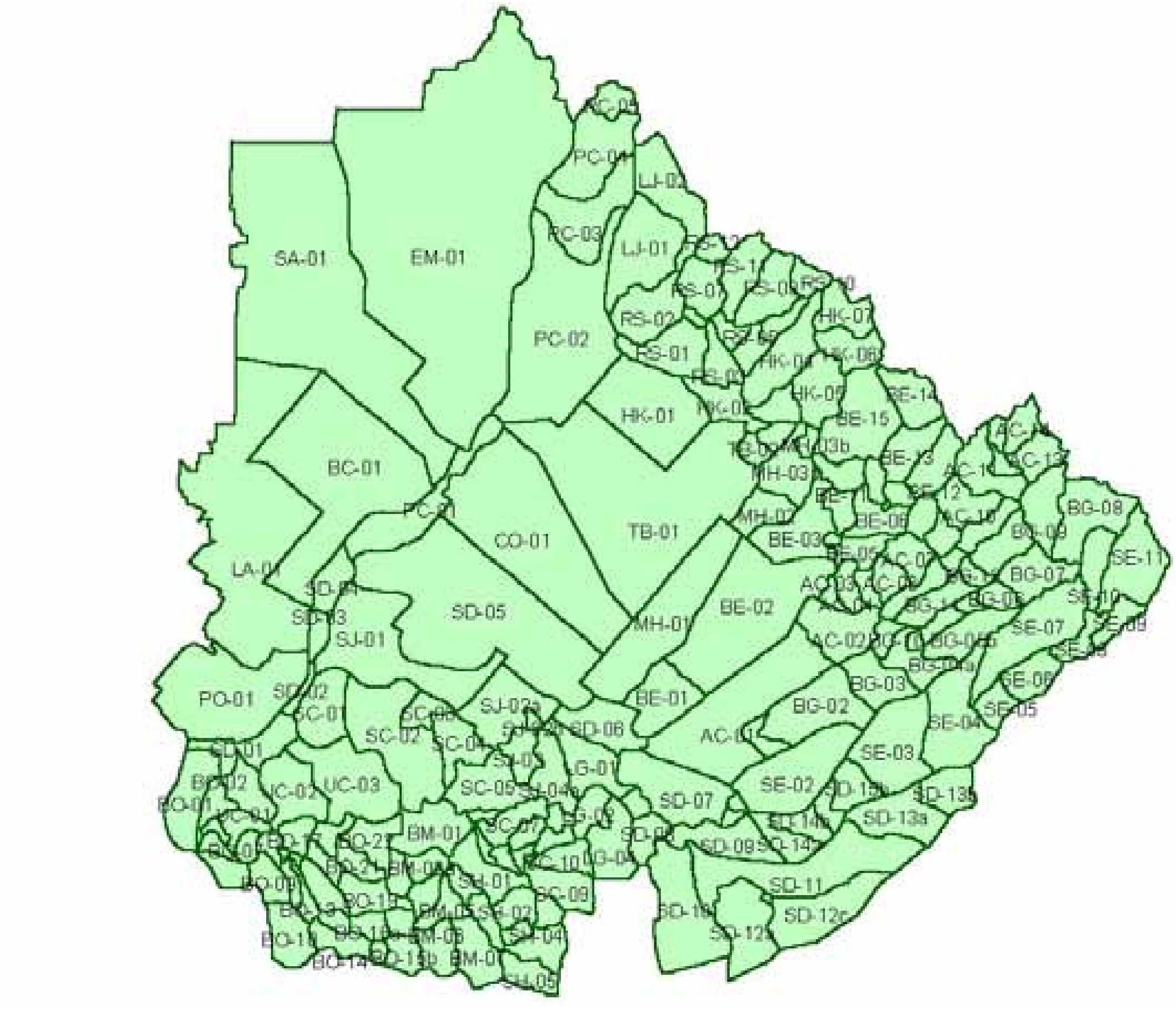

Figure 10. Location of riparian reaches as represented by labeled local drainages

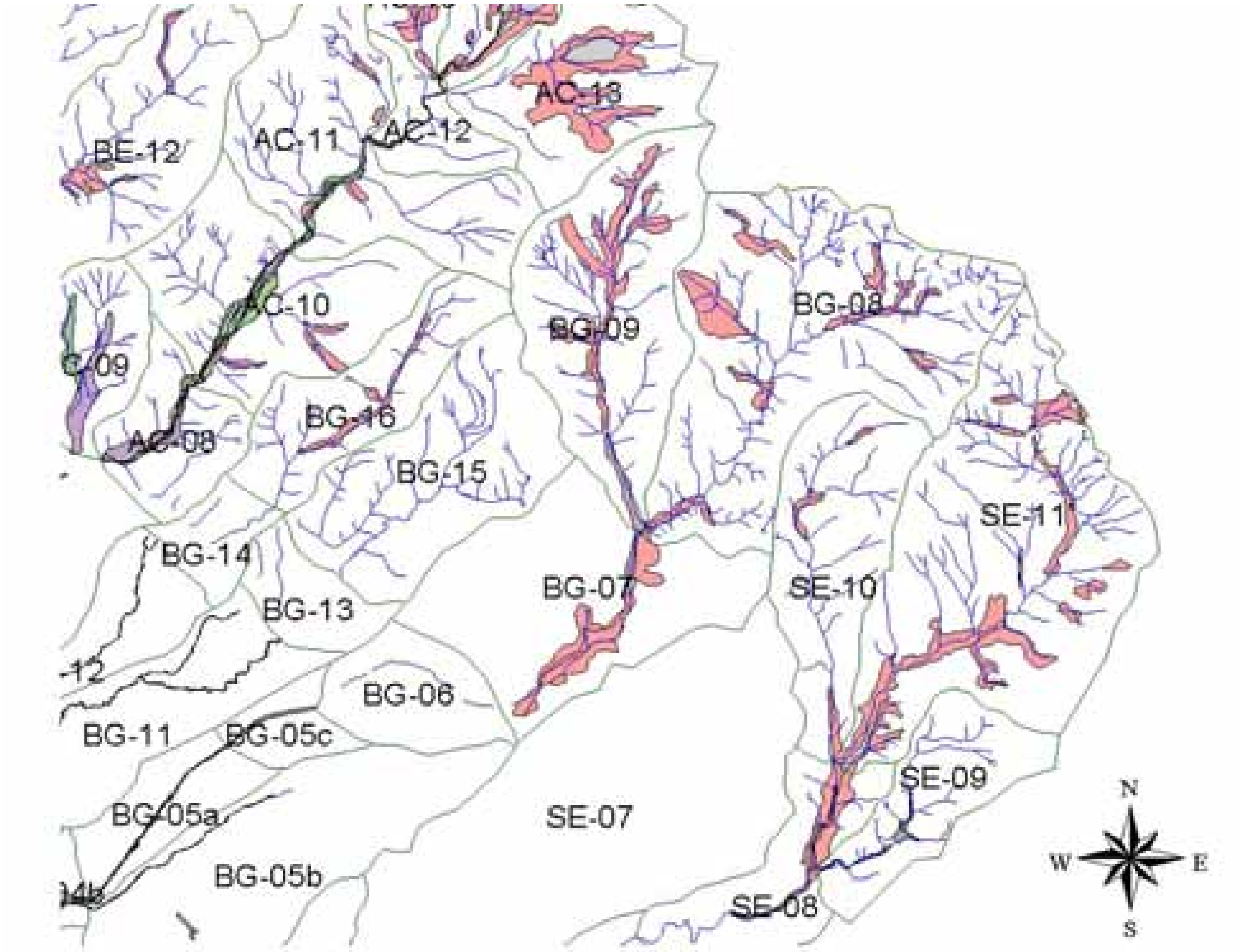

Figure 11. Riparian ecosystems in the Borrego and Serrano Creeks area consisting of stream channels (blue lines) and wetlands (colored polygons representing wetland ratings from Lichvar (2000)

Figure 13 illustrates how the results can be used to summarize the baseline condition for riparian ecosystem integrity in the watershed, and compare riparian reaches. In the figure, labels represent the hydrologic integrity index (i.e., the sum of scores for indicators associated with hydrologic integrity). The highest possible score is 30 since six indicators are used to calculate the index. The gradient, from light to dark green, provides an easy way to visually identify areas of high hydrologic integrity in the watershed. Users with personal knowledge of the watershed will recognize that index values are low in areas of urban and agricultural development and higher in the more remote, undeveloped areas. Figures 14 and 15 illustrate the

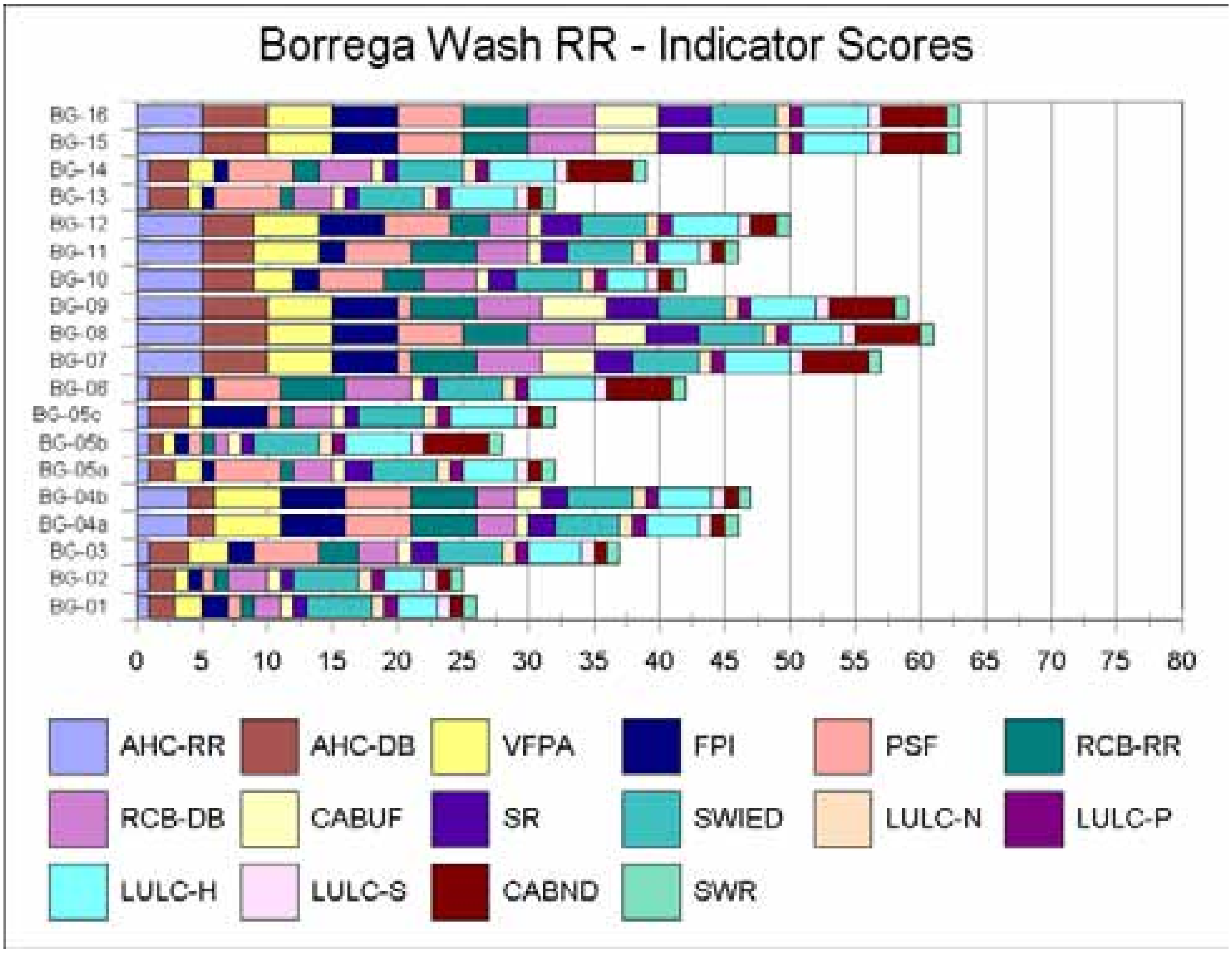

Figure 12. Scores for individual indicators in the Borrego Canyon drainage basin (indicator codes are provided in the Indicator Definitions, Metrics, and Reference Condition Section)

results for water quality and habitat integrity indices with possible scores of 45 and 30 respectively.

The results also provide the mechanism for addressing the third task (see Project Objectives above). This is to determine which of several proposed alternative development scenarios will result in the least impact to riparian ecosystem integrity in the watershed. By simulating changes that can be expected to occur as a result of a proposed alternative scenario (i.e., changes in land use, hydraulic conveyance, etc.) in terms of indicators, the existing information and tools can be used to generate new indictor scores and indices for riparian reaches. These scores and indices

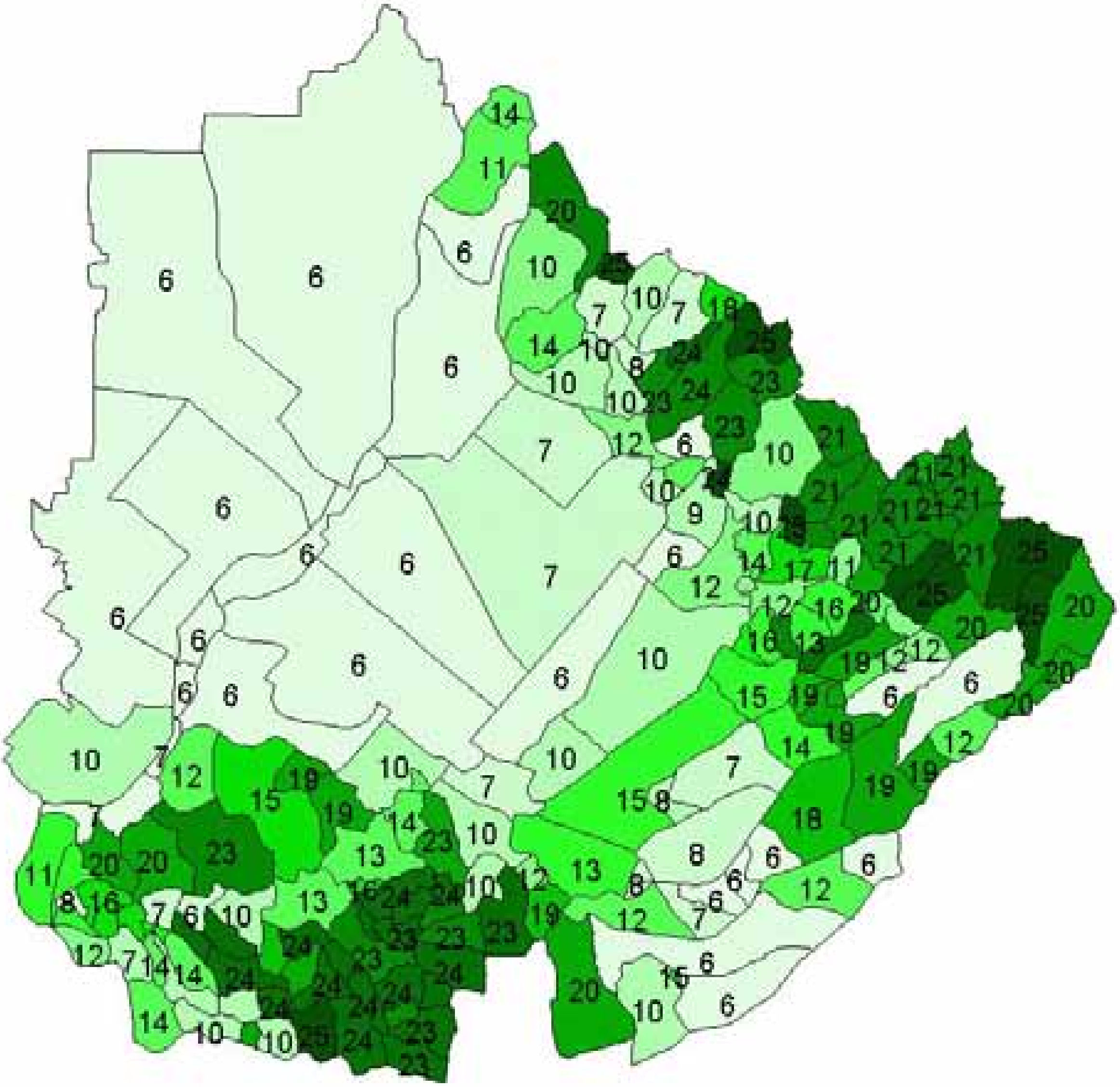

Figure 13. Hydrologic integrity indices (i.e., sum of hydrologic indicator scores with a possible total of 30) for riparian reaches in San Diego Creek Watershed

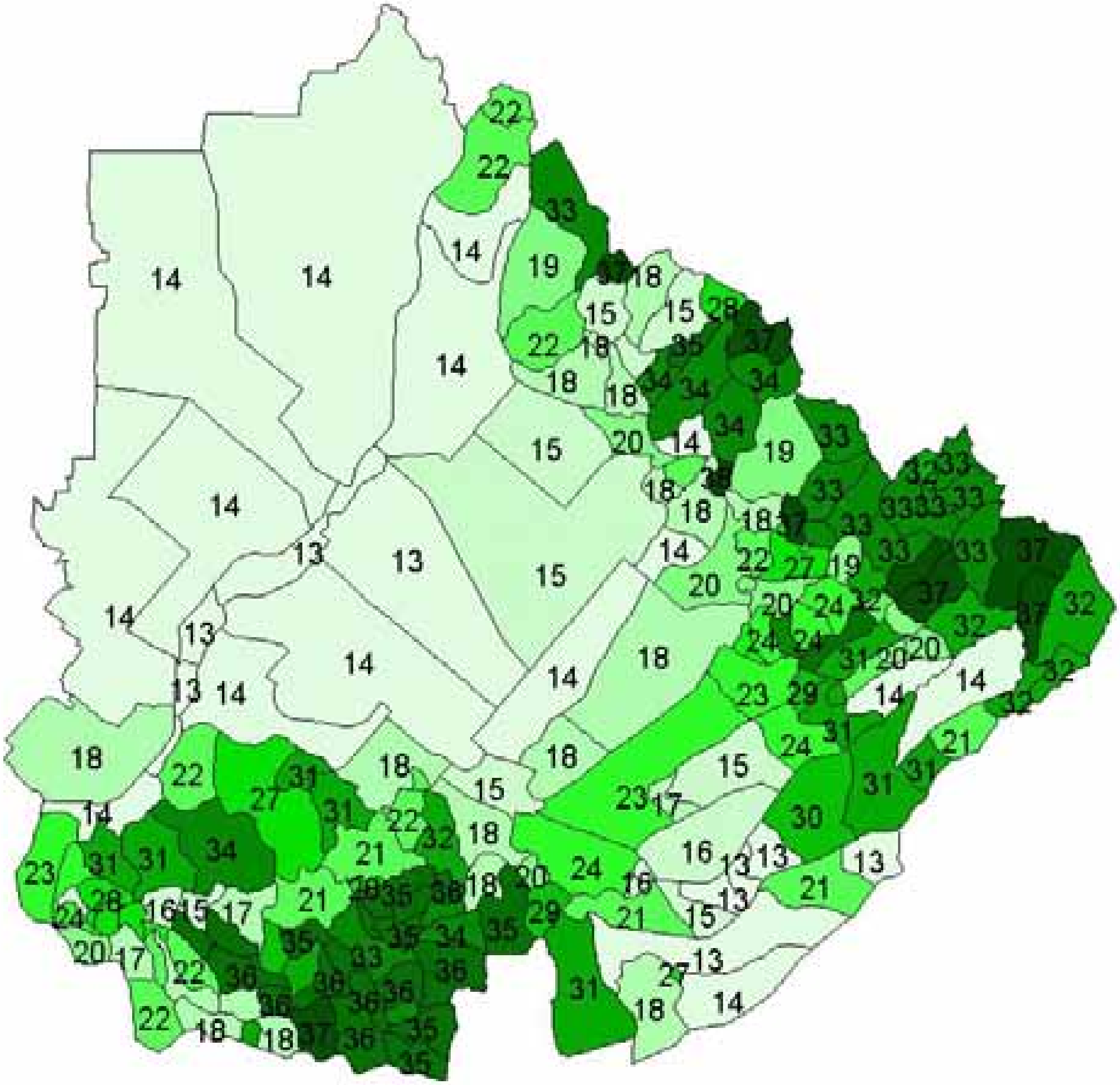

Figure 14. Water Quality integrity indices (i.e., sum of water quality indicator scores with a possible total of 45) for riparian reaches in San Diego Creek Watershed

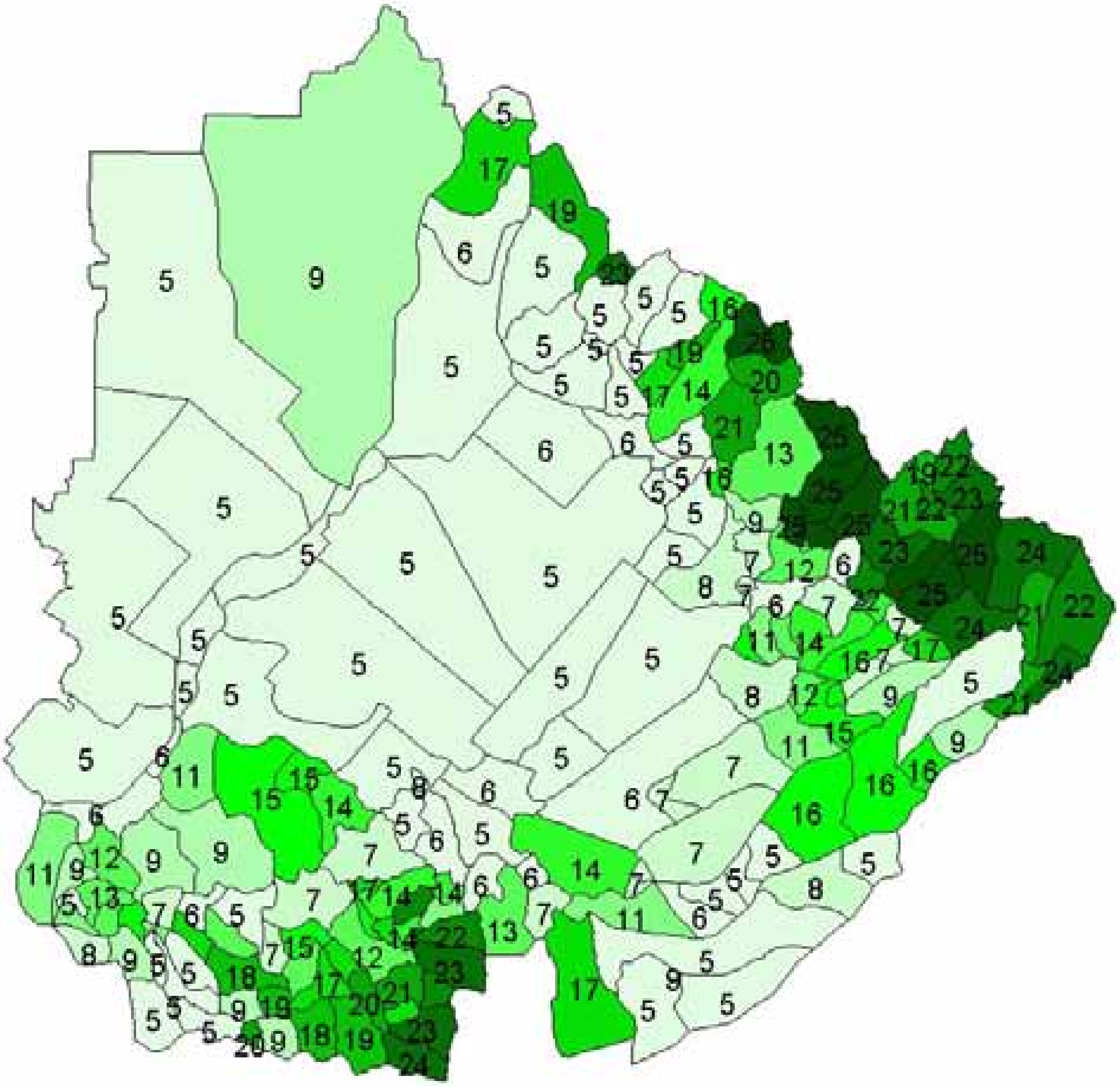

Figure 15. Habitat integrity indices (i.e., sum of habitat indicator scores with a possible total of 30) for riparian reaches in San Diego Creek Watersheds

can then be compared with baseline indicator scores and integrity indices to show how the proposed alternative scenarios will differentially impact riparian ecosystem integrity in the watershed.

We look forward to working with the Los Angeles District, other agencies, and stakeholders in completing this third task.

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* used as reference only, not cited in text

Appendix A: Spreadsheet Information and Guidelines

Information collected during field work and calculated during ArcView spatial analysis was input into an Microsoft Excel spreadsheet. Table A1 provides a listing of fields in this spreadsheet. This spreadsheet can be found in the following location on the CD: c:\san diego creek final\spreadsheets\san diego creekl.xls. The U. S. Army Corps of Engineers – Los Angeles District Regulatory Branch is responsible for distributing this information in an electronic format. A partial listing of information for the Bell Canyon reaches is provided in Table 13.

Table A1. List of spreadsheet fields and method of obtaining data

Field Description	Method
Riparian Reach ID	Field
Drainage Basin	Field
USGS 7.5 Minute Topograpic Quad	GIS
Mainstem Downstream End Coordinates (UTM)	GIS
Mainstem Upstream End Coordinates (UTM)	GIS
Size of Mapped Riparian Ecosystem in Riparian Reach Local Drainage (ha)	GIS
Size of Mapped Riparian Ecosystem in Riparian Reach Drainage Basin (ha)	GIS
Size of Riparian Reach Local Drainage (RRLD) (ha)	GIS
Length of RRLD Perimeter (m)	GIS
Size of Riparian Reach Drainage Basin (RRDB) Area (ha)	GIS
Valley Type (Rosgen)	Field
Valley Length (m)	Field / GIS
Valley Width (m)	Field / GIS
Mainstem Downstream End Elevation (m)	GIS
Mainstem Upstream End Elevation (m)	GIS
Valley Slope (%) (Estimated From 7.5 Minute Topo)	Calculated
Engineered Channel Type or Rosgen Stream Type	Field
Mainstem Channel Length in RRLD (m) (Smith)	GIS
Mainstem Channel Length in RRDB (m) (Smith)	GIS
Mainstem and Tributary Channel Length in RRLD (m) (Lichvar)	GIS
Mainstem and Tributary Channel Length in RRDB (m) (Lichvar)	GIS
Mainstem Channel Length / Mainstem Channel and Tributary Channels Length	Calculated
Drainage Density	Calculated
Channel Slope	Calculated
Sinuosity	Calculated
Bankfull Width (ft)	Field
Bankfull Width (m)	Calculated
Floodprone Width (ft)	Field
Floodprone Width (m)	Calculated

Bankfull Maximum Depth (in)	Field

Table A1 continued. List of spreadsheet fields and method of obtaining data

Bankfull Maximum Depth (cm)	Calculated
Bankfull Mean Depth (in)	Field
Bankfull Mean Depth (cm)	Calculated
Bankfull Cross-Sectional Area (m^2)	Calculated
Width / Depth Ratio	Calculated
Entrenchment Ratio	Calculated
Natural Channel Substrate Bedrock / Boulder (%)	Field
Natural Channel Substrate Cobble (%)	Field
Natural Channel Substrate Gravel (%)	Field
Natural Channel Substrate Sand (%)	Field
Natural Channel Substrate Silt / Clay (%)	Field
Indicator 1 % of Channel in RRLD with Altered Hydraulic Conveyance	Field
Indicator 2 % of Channel in RRDB with Altered Hydraulic Conveyance	GIS
Indicator 3a % of Flood Prone Area with Native Riparian Vegetation	Field
Indicator 3b % of Flood Prone Area with Native Riparian Vegetation	GIS
Indicator 4 % of Floodplain Present and not Isolated from Channel	Field
Indicator 5 % of Channel with Perennialized Stream Flow	Field
Indicator 6 % of Flood Prone Area in the RRLD with Riparian Corridor Breaks	Field
Indicator 7 % of Flood Prone Area in the RRDB with Riparian Corridor Breaks	Field
Indicator 8a % of Buffer (100m) with Culturally Altered LULC types	Field
Indicator 8b % of Buffer (100m) with Culturally Altered LULC types	GIS
Indicator 9 Sediment Regime Condition Index of Channel in RRLD	Field
Indicator 10 % of RRDB with Surface Water Imported, Exported or Diverted	GIS
Indicator 11 % of LULC Contributing to Nutrient Increase in Surface Waters	GIS
Indicator 12 % of LULC Contributing to Pesticide Increase in Surface Waters	GIS
Indicator 13 % of LULC Contributing to Hydrocarbon Increase in Surface Waters	GIS
Indicator 14 % of LULC Contributing to a Sediment Increase in Surface Waters	GIS
Indicator 15 % of REBLD with a Culturally Altered Boundary	GIS
Indicator 16 % of RRDB with Surface Water Retention	GIS
Indicator 17 % of RRDB with an Increased Runoff Coefficient	GIS
Indicator 1 Score	Calculated
Indicator 2 Score	Calculated
Indicator 3a Score	Calculated
Indicator 3b Score	Calculated
Indicator 4 Score	Calculated
Indicator 5 Score	Calculated
Indicator 6 Score	Calculated
Indicator 7 Score	Calculated
Indicator 8a Score	Calculated
Indicator 8b Score	Calculated
Indicator 9 Score	Calculated

Indicator 10 Score	Calculated

Table A1 continued. List of spreadsheet fields and method of obtaining data

Indicator 11 Score	Calculated
Indicator 12 Score	Calculated
Indicator 13 Score	Calculated
Indicator 14 Score	Calculated
Indicator 15 Score	Calculated
Indicator 16 Score	Calculated
Indicator 17 Score	Calculated
Hydrologic Integrity Index	Calculated
Water Quality Integrity Index	Calculated
Habitat Integrity Index	Calculated
Ecosystem Integrity Index	Calculated
Hyperlink to Valley Overview Photo	*
Hyperlink to Terrace Overview Photo	*
Hyperlink to Channel View Photo	*
Hyperlink to Selected Photo 1	*
Hyperlink to Selected Photo 2	*
Hyperlink to Field Data Sheet Side 1	*
Hyperlink to Field Data Sheet Side 2	*
Hyperlink to Scanned Aerial Photo 1	*
Hyperlink to Scanned Aerial Photo 2	*
Hyperlink to Scanned Aerial Photo 3	*
Hyperlink to Scanned Aerial Photo 4	*
Hyperlink to Scanned Aerial Photo 5	*
Hyperlink to Scanned Aerial Photo 6	*
Hyperlink to Scanned Aerial Photo 7	*

* not applicable

Appendix B: GIS Information and Guidelines

Spatial information collected and utilized for spatial analysis during the project was collected and saved as an ArcView project file. All themes and images in the project file are in a UTM – NAD83 projection in meter units. The U. S. Army Corps of Engineers – Los Angeles District Regulatory Branch is responsible for distribution of this information.

The ArcView GIS information for the San DiegoWatershed was organized under the San Diego Creek Folder as follows.

1. San Diego Creek Folder (c:\san diego creek final)

Project Folder (c:\san diego creek final\apr files\san diego creek.apr)

AVL File Folder (c:\san diego creek final\avl files\)

ArcView "avl" files for loading pre-selected settings for themes including:

geology.avl – "avl" settings for geology.shp
habitat indicator score sum.avl – "avl" setting for habitat indicator score sum.shp
hotlink.avl – "avl" settings for all hotlinked image shape files
hydro indicator score sum.avl – "avl" setting for hydro indicator score sum.shp
lulc.avl – "avl" settings for land use / land cover
roads.avl – "avl" settings for roads
rrld.avl – "avl" settings for ssurgo.shp
streams.avl – "avl" settings for ssurgo.shp
ssurgo.avl – "avl" settings for ssurgo.shp
wous1.avl – "avl" settings for wous1.shp with Lichvar (2000) ratings
wous2.avl – "avl" settings for wous2.shp with Lichvar (2000) ratings
wq indicator score sum.avl – "avl" setting for wq indicator score sum.shp

Image Files (c:\san diego creek final\image files\)

ArcView image files including:

usgstopo1.tif - USGS 7.5 minute topo coverager for most of watershed
usgstopo2.tif - USGS 7.5 minute topo coverager for southeast corner of watershed

eagle.tif – true color partial aerial photo coverage of southern portion of watershed

Shape Files (c:\san diego creek final\shape files nad83 zone 11 m)

ArcView theme shape files including:

habitat indicator score sum.shp – Habitat integrity indices for all riparian reaches
hydro indicator score sum.shp – Hydrologic integrity indices all riparian reaches
geology.shp: Surficial geology
lulc.shp - Land Use / Land Cover
roads.shp - Major roads in the watershed
rrld.shp - Riparian Reach Local Drainage Boundaries
streams.shp – Working version of stream network for San Diego Creek (D. Smith)
surgo.shp - SURGO soils
watershed.shp – Watershed boundary
wous1.shp - Waters of the US vectors (R. Lichvar)
wous2.shp - Waters of the US polygons (R. Lichvar
wq indicator score sum.shp – Water quality integrity indices all riparian reaches

ArcView hotlinked images attached to shape files including:

aerial1.shp – Hotlink to scanned aerial photo 1 of riparian reach
aerial2.shp – Hotlink to scanned aerial photo 2 of riparian reach
aerial3.shp – Hotlink to scanned aerial photo 3 of riparian reach
aerial4.shp – Hotlink to scanned aerial photo 4 of riparian reach
aerial5.shp – Hotlink to scanned aerial photo 5 of riparian reach
aerial6.shp – Hotlink to scanned aerial photo 6 of riparian reach
aerial7.shp – Hotlink to scanned aerial photo 7 of riparian reach
channel view.shp – Hotlink to channel view photo
field sheet 1.shp – Hotlink to field data sheet 1 scanned image
field sheet 2.shp – Hotlink to field data sheet 2 scanned image
indicator scores graph.shp – Hotlink to graph of indicator scores for riparian reach
terrace overview.shp – Hotlink to terrace overview photo
valley overview.shp – Hotlink to valley overview photo

“JPG” Files (c:\san diego creek final\aerials), (c:\san diego creek final\hyperlinked pics), (c:\san diego creek final\graphs), and (c:\san diego creek final\field forms)

Files with a “jpg” extension. These include aerial photographs, valley, terrace, and channel photos of each riparian reach, data sheets, and indicator score graphs. These files are hyperlinked in the Excel spreadsheet discussed in Appendix A, and “hot linked” in ArcView. However, in order for the hot links to work in ArcView, you must purchase extension software to access “jpg” image files in ArcView because the hotlink procedure in the ArcView program limited to one link, and “jpg” image files are not supported. There are several ArcView extensions available. We have found the PowerLink extension software to perform well, but others might be just as suitable. PowerLink can be purchased on line from http://www.spatial-online.com/dev/overview.asp. for $70.

Project sponsors and other end users have at least two choices for using the information in the folders above. The easiest thing to do is to copy the san diego creek final folder along with the appropriate subfolders (i.e., apr files, avl files, image files, shape files nad83 zone11 m, aerials, field forms, hyperlinked pics, and graphs) to the c:\ drive of your computer and simply open the san diego creek project in the apr files folder in ArcView. If this is the option you choose, it is critical that the folder is copied to the c:\ drive, and that you do not change the names of any folders or files.

The other option is to build a new ArcView project using the files in the themes and images folders and your knowledge of ArcView.

Appendix C: Database Information and Guidelines

Selected information collected during field work and calculated during ArcView spatial analysis was placed in a Microsoft Access database. The primary data access screens in this database are described below. The U. S. Army Corps of Engineers – Los Angeles District Regulatory Branch is responsible for distributing this information.

Screen 1

Drop down pick list of all riparian reaches

Screen 2

Drop down picklist or list of bullets for each of the following:

- Summary Report for Riparian Reach (see Figures 8 and 9 above).
- Valley Overview Photo
- Terrace Overview Photo
- Channel Photo
- Aerial Photo 1
- Aerial Photo 2
- Aerial Photo 3
- Aerial Photo 4
- Aerial Photo 5
- Aerial Photo 6
- Aerial Photo 7
- Field Data Sheet 1
- Field Data Sheet 2

Note that the aerial photos, pictures, and field data sheets in the database are the same as those available as hyperlinks in the Excel spreadsheet, and as hotlinks in ArcView.