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Existing and Desired Conditions for Riparian and Aquatic Ecosystems

Supplement to

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USDA Forest Service Southwestern Region



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Cover Photo – Rattlesnake Spring, Coconino National Forest, Arizona. Photo by: Tom Runyon (USFS)

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This guide supplements the Southwestern Region Riparian and Aquatic Ecosystem Strategy (RAES) by establishing desired conditions and identifying information sources for existing condition and trends. A summary of the physical and biological properties of riparian, aquatic, and groundwater-dependent ecosystems is included, along with some features of disturbance regimes including beaver. The desired conditions were written from the perspective of the *coarse filter* and broadly applicable ecological conditions (36 CFR 219.6) and not for individual species or localities for which more specific desired conditions may be needed. Desired conditions are conveyed in three overlapping sections for riparian ecosystems, aquatic ecosystems, and stressors to aquatic and riparian ecosystems. This guide also offers data sources and references for determining existing conditions.

The intent of this guide is for strategic- and project-level development of desired conditions. What follows are descriptions and suitable ecological characteristics consistent with the 2012 Plan Rule:

A desired condition is a description of specific social, economic, and/or ecological characteristics of the plan area, or a portion of the plan area, toward which management of the land and resources should be directed. Desired conditions must be described in terms that are specific enough to allow progress toward their achievement to be determined, but do not include completion dates (36 CFR 219.7(e)(1)(i)).

This guide is consistent with regional conventions and priorities including the RAES, and the regional Forest Plan assessments and ecosystem characteristics that have been analyzed to date. This guide is aligned with the structure, content, and scope of the desired conditions document written for forest and woodland systems of the Southwestern Region (USDA Forest Service 2019).

Introduction

Aquatic and riparian ecosystems occur adjacent to one another and are influenced by the dynamics of groundwater and surface water, within a context of watersheds and upland systems (Gregory et al. 1991). Smith et al. (2018) summarize the biotic, chemical, and physical interactions between aquatic and riparian ecosystems on three dimensions “with one dimension extending from the headwaters of a stream to its mouth [longitudinal], the second dimension extending from the groundwater zone to the canopy of vegetation [vertical], and the third dimension extending from the stream bed to the outer extent of the floodplain [lateral]” (Stanford and Ward 1988, 1993; Vannote et al. 1980). Riparian and aquatic ecosystems reflect the range of Southwest life zones, often integrated with or bounding upland ecosystem types. Riparian and aquatic ecosystems are subject to fire, wind, herbivory, erosion, and other processes and are especially influenced by hydrology. While this guide is largely focused on desired conditions,

information sources useful for determining existing conditions are included in the summary tables within each of the three major sections of the document.

Desired conditions describe the desired appearance and function of ecosystems when restored and maintained. They were developed as a basis for dialogue on desired conditions among interdisciplinary teams and with the public at the local level. The RAES team understands that local biotic and abiotic conditions vary across the region and that there may be need for adjustments to account for unique situations. These desired conditions do not account for all of the ecological, social, and economic factors that might be unique to different areas; such factors should be considered at the local administrative unit to produce a complete set of desired conditions, including descriptions for special areas of interest or descriptions aimed at conservation of specific species. Finally, the desired conditions described in this document are intended to be adjusted by the adaptive management process to assure consistency with current science and managerial experiences.

Desired conditions are necessarily both qualitative and quantitative. Quantitative desired conditions are represented by indicators (ecological, social, and economic) embedded in qualitative descriptions. Qualitative descriptions convey an overall vision of desired features and patterns to interdisciplinary teams, decision makers, and the public. Quantitative information offers enough detail so that on-the-ground accomplishments and progress can be measured. For example, in riparian zones it is desirable that “stream channels and floodplains are connected” – this is a useful qualitative description. For application, it’s necessary to complement the statement with indicators, such as plant composition or geomorphological attributes, which objectively demonstrate how connectivity is expressed and measured. Qualitative and quantitative desired conditions are integrated with one another to communicate where management of the land and resources is directed in specific enough terms for consistent application and evaluation.

Physical and Biological Properties of Riparian Ecosystems

Riparian corridors are topographically delineated to include both aquatic and riparian ecosystems based on distinctive resource values and characteristics. This report concerns riparian ecosystems associated with both lotic (streams, rivers, washes, etc.) and lentic environments (ponds, lakes, springs, seeps, playas, wetlands). Riparian ecosystems represent a transition between the aquatic ecosystem and the adjacent upland ecosystems. It is distinct from the surrounding lands because of unique soil, vegetation, and hydrologic characteristics that are strongly influenced by frequent flooding and free or unbound water in the soil.

Healthy riparian areas provide a number of ecosystem services. Riparian vegetation provides for water quality benefits by filtering and storing sediments, nutrients, and pollutants, while root systems stabilize stream channels. Riparian vegetation reduces the impacts of flood peaks by

slowing and spreading flood waters, and helps to regulate water temperature through shading. Riparian areas serve as key recharge zones for renewing groundwater supplies and provide groundwater discharge to maintain base flows in perennial streams during dry seasons. They also maintain biodiversity through the provision of wildlife habitat including shelter and food for fish and other aquatic organisms. Riparian areas also sequester carbon, provide recreational opportunities, provision for domestic, commercial, and agricultural water supplies, and offer indirect economic benefits through activities such as birding.

Riparian areas and the adjacent uplands have similar physical and biological processes, but differ due to differences in soil characteristics, water sources, and disturbance regimes. Soil differences are due to depositional and erosional processes stemming from frequent flood events. Riparian soils have higher spatial diversity, are typically younger, and lack well-developed soil horizons relative to their terrestrial upland counterparts.

Given moisture availability, riparian areas have greater vegetation densities than surrounding uplands and possess different wildlife diversity. Precipitation is the principal water source for upland vegetation. In contrast, riparian areas receive water from upland sources in the form of overland flow, shallow subsurface flow, and ground water recharge, and from aquatic systems, in the form of out-of-bank flows, infiltration into stream banks, and hyporheic flow from upstream. Riparian areas consequently have access to a greater volume of water compared to adjacent uplands.

Riparian areas are also adapted to frequent disturbance regimes, primarily flooding to which uplands are not normally exposed. Channel characteristics of streams and rivers (their dimensions, patterns, and profiles) are shaped by the range of water flows and sediment loads produced by the contributing watershed. Flow regimes are essential to stream channel morphology and provide the physical template for riparian and aquatic ecosystems, including everything from frequent, low magnitude flow events to relatively rare, high magnitude events. In many systems, frequent floods (approximately a 1.5-year return interval) are the dominant channel-forming flows and do much of the work over time at moving water and sediment and shaping the channel system (Dunne and Leopold 1978). High magnitude, less frequent flood flows can also perform significant channel work. Stream channel characteristics can also be affected by management activities (runoff from roads, bridges, domestic animal crossings, etc.) that disrupt the sediment balance, flow regime, groundwater levels, or the riparian vegetation.

Riparian areas provide habitat for a vast diversity of wildlife. In the Southwest it has been estimated that up to 60% of threatened and endangered vertebrate species are riparian (Johnson 1989). Riparian areas also have higher species richness and density than the surrounding uplands (Jobin et al. 2004; Lyon and Gross 2005). Due to the linear nature of riparian areas, they also serve as corridors that provide dispersal routes for many species, and act as filters, sinks, and sources of biological and non-biological materials (Forman 2014; Malanson 1993).

Groundwater-dependent ecosystems, including springs, seeps, wetlands, and fens represent important types of riparian areas. The constant source of water at springs and seeps leads to the abundant growth of plants and many times to unique habitats for endemic species like spring snails (Glasser et al. 2007). Wetlands occur in widely diverse settings ranging from pond and lake margins to floodplains to mountain valleys. Fens are less acidic and have higher nutrient levels than other types of peatlands and are able to support a much more diverse plant and animal community. Wetlands and fens provide many of the same benefits provided by stream riparian areas.

Physical and Biological Properties of Aquatic Ecosystems

The Forest Service stewards over twenty million acres of land and water in the Southwestern Region. Within the region there are 33,570 acres of lakes and 146,321 miles of stream. Only about 3% of total stream miles (4,360 miles), are perennial (flowing year round; See Appendix F). The majority of stream miles are ephemeral channels that flow only in response to snowmelt or during periods of storm water runoff. The percent of perennial streams on individual forests range from as little as one percent on the Coronado and Kaibab National Forests to as much as seventeen and eighteen percent on the Santa Fe and Carson National Forests.

There are many diverse types of aquatic habitats present within a given stream reach depending on stream type. Typically, streambeds undulate in elevation in a regular repeating pattern. Shallow, higher velocity areas (riffles and runs) alternate with deeper, lower velocity areas (pools). Diversity of instream habitat features within a reach is crucial for the various life stages of fish and other aquatic species. Low velocity areas are especially important for larval fish development. Adult fish can occupy many different types of habitats depending on the species and their life history. Many larger-bodied fish such as trout, chubs, and suckers use riffles and runs for feeding and pools for resting. Some of the smaller bodied species such as loach minnow, spend most of their life within high velocity riffle sections, hiding under large cobbles, which create small areas of low velocity water. Loose substrate is critical for creating these microhabitats. The quantity of instream habitat types that is present at a given time varies depending on flow and substrate condition. At higher flows, the diversity of instream habitat features often become less evident (Dunne and Leopold 1978). Substrates embedded with fine sediments can decrease habitat diversity for smaller fish and aquatic invertebrates.

Water temperature affects the type and abundance of aquatic organisms. For example, salmonid fish species are adapted to cold water temperatures. Water temperatures in many smaller stream reaches are significantly influenced by shade from overhanging vegetation near the channel and can be influenced by groundwater discharge to the channel as well (Brown 1969; Hauer et al. 2000; Naiman et al. 2000 in Zaimes 2007). Channel shape influences water temperature, with narrow deep channels generally maintain cooler water than wide shallow systems. Shade and

groundwater input may be key factors in maintaining resilient streams in the face of climate change (Ziegler et al. 2013).

The banks of a channel form a critical interface between terrestrial and aquatic ecosystems. Many species, particularly aquatic invertebrates, depend on habitat at the stream bank as a site to emerge and pupate into adult forms (Benke and Wallace 1990). By providing plant materials, such as litter, to the aquatic system, the habitat at the channel edge plays a critical role in carbon dynamics of the instream community, especially in small first and second order streams (Giller and Malmqvist 1998; Vannote et al. 1980; Wipfli 2005).

Riparian areas support phreatophyte and occasionally upland tree species that may enter the stream system and become part of the coarse woody debris load (woody material greater than 3 in. in diameter; Platts et al. 1987). Coarse woody debris (CWD) represents an important habitat in smaller rivers and streams and can have significant effects on channel geometry, creating a diversity of habitat elements such as hiding cover and thermal refugia (Beschta 1979; Harmon et al. 1989; Maser and Sedell 1994). The CWD also provides important habitat for a wide range of reptiles (Szaro and Belfit 1986; Warren and Schwalbe 1985).

Groundwater-dependent ecosystems are typically present where the water table intersects the land surface. They can be important sources of water to streams and other surface water features by maintaining or prolonging baseflows. Wetlands can receive inflow from groundwater, recharge groundwater, or both. Fens are peat-forming wetlands that receive recharge and nutrients almost exclusively from groundwater (Chadde et al. 1998). These systems tend to function as carbon sinks and can store large amounts of carbon for thousands of years, providing an important ecosystem service (Charman 2002; Chimner and Cooper 2003).

Disturbance Regimes and Temporal Diversity

Riparian plant communities often experience significant changes over time resulting in habitat patches of differing ages in a small spatial area. The main drivers of habitat variation over time are flooding, deposition and scour of sediments, recruitment and redistribution of large wood, regeneration of vegetation, channel avulsion, and drought (Stanford et al. 2005). Floods are an important regenerative mechanism for many types of riparian habitat (Fierke and Kauffman 2005; Miller et al. 1995; King and Louw 1998) and are a natural part of a stream's flow regime. A flood is any climatically controlled, relatively high streamflow that overtops the natural or artificial banks in a given stream reach, thereby being of geomorphic significance. Where a flood plain exists, a flood is any flow that spreads over or inundates the flood plain. Floods play a critical role in maintaining functioning aquatic and riparian ecosystems by removing and depositing sediment, woody debris, nutrients, and by creating site conditions critical to the regeneration of many native plant and animal species. Floods can remove herbaceous and woody species and accumulated woody debris, scour substrates, deposit sediments, and create new sites

for germination and establishment of plant species. Floods connect the stream to its floodplain and allow for exchange of energy and nutrients. Many riparian woody species such as cottonwood and willow require the open mineral seedbed created by scouring for successful germination. Slowly receding water table elevations following flood events are important to enable root growth of newly recruited riparian vegetation.

Flooding is critical for the life history of some types of fish. Flooding may cue spawning events, loosen and clean the substrate, and create habitat diversity. Many populations of native fish species in the Southwest respond positively to flood events, while areas that have modified flows are dominated by non-native fish. Non-native species are often much more dominant in areas with an altered flow regime. Altered flows can be caused by dams, diversions, and groundwater pumping. (Olden and Poff 2005; Propst et al. 2008)

Altered hydrology as a result of water diversion can cause encroachment of vegetation into stream channels and mortality in the outer riparian area (Harris 1986; Martin and Johnson 1987; Sedgwick and Knopf 1989; Webb and Leake 2006). The reduction in the magnitude, frequency, or duration of flood events due to a variety of human interferences (impoundment, diversion, ground water pumping, etc.) can lead to both increases in plant biomass from the lack of scour as well as mortality of many obligate riparian plants that would normally establish in riparian areas that are no longer frequently inundated. An uncharacteristic increase in riparian biomass often results from the spread of exotic and upland woody species that are adapted to the altered hydrologic regime and that can proliferate with the relative abundance of moisture. Reducing the amount of water passing through these areas can decrease the width of the riparian zone due to mortality of species, especially in the outer riparian zone and change the stream morphology. Other actions that confine stream channels (such as roads) or cause incision result in a narrowing of the riparian zone.

Engineering of Aquatic and Riparian Ecosystems by Beaver

The distribution and abundance of beaver in North America have been dramatically reduced since the arrival of Europeans. A large and growing body of science indicates that beavers play an integral role in aquatic and riparian ecosystems by dam-building and enhancing water storage, raising water tables, prolonging periods of water delivery, and providing diverse and complex habitat types for aquatic and riparian obligate species. These effects collectively enhance the functionality of riparian and aquatic ecosystems while also increasing their resilience to climate change. The loss and persistent absence of beavers from aquatic and riparian ecosystems has been driven by direct (trapping for fur markets, hunting for food, killing nuisance individuals, etc.) and indirect effects (loss of woody vegetation that provides food and dam-building materials from riparian vegetation communities due to preferential browsing by domestic and wild ungulates). Restoring suitable riparian habitat, including the crucial woody component, that can support robust beaver populations in historically occupied range has the potential to be a

valuable element of effective restoration in these systems. (Lokteff et al. 2013; Macfarlane et al. 2014; McColley et al. 2011; McKinstry et al. 2007; Wheaton 2013).

Development of Desired Condition Concepts

The development of riparian and aquatic desired conditions was informed by revised Forest Plans of the Southwestern Region and the RAES, both of which were based on restoration principles, geomorphology, ecosystem services, a broad range of scientific publications, and monitoring and assessment protocols on riparian ecology. Desired conditions were abstracted from final and draft revised Forest Plans which provided most of the needed qualitative descriptions and some indicators. When necessary, indicators with greater specificity were added to meet the 2012 Plan Rule requirements for desired conditions (36 CFR 219.7(e)(1)(i)). Scientific literature and regional information on riparian and aquatic systems provided the necessary scientific underpinning, while available data sources, regional conventions, and established approaches and methods served as sideboards for determining existing and desired conditions (e.g., Yanoff and Bradley 2009a, 2009b). The resulting desired conditions are supported by peer-reviewed science and are based on the concept of *reference condition*.

Reference Condition and the Natural Range of Variation

The reference condition for a particular indicator is a science-based benchmark that provides the best inference of ecological integrity. Reference conditions are often, but not always, based on the natural range of variation (NRV; FSM 1909.12.14.a). Reference conditions are most useful when expressed as a range rather than a specific threshold, but it isn't always possible or warranted to have ranges, as in the case of a particular water quality standard. Desired conditions and reference conditions are not always the same, since desired conditions also account for socioeconomic factors and feasibility; however, desired conditions need to reflect reference conditions to the extent that they support ecological integrity. Reference conditions are updated with new information that represents the best available science, and updated when there are new ecosystems conditions that have lasting effects on the potential of the system (e.g., installation of a dam, warming climate).

Each indicator is represented by a reference condition. As mentioned, reference conditions are often derived from NRV, those ecosystem patterns of the current climatic period that existed prior to European settlement, and significant interruption of disturbance processes. But the NRV is not necessary or appropriate when:

- Aquatic and riparian systems are constructed or modified and are likely to remain modified (e.g., due to water rights) but yet provide important habitat;
- The indicator does not rely on NRV, such as wetland condition rating of function;

- The NRV is not known, such as with riparian corridor connectivity; or
- Specific legal and policy requirements for managing habitat for federally listed species may not be consistent with managing for NRV.

Either way, the reference condition needs to reflect the current potential of the ecosystem and be derived from suitable inferences of ecological sustainability that ultimately support ecosystem function.

Various concepts and processes were used to develop and describe desired conditions for riparian, wetland, and aquatic resources of the Southwest. The best available science was used to determine historic conditions, where appropriate, as a basis for the development of desired conditions for management planning and projects. Reference conditions for riparian, wetland, and aquatic resources are frequently used to define restoration goals, to estimate the restoration potential of sites, and to evaluate the success of restoration efforts. Reference conditions are useful for understanding the normal variability in composition, structure, processes, and functions among sites and for understanding the dynamic nature of ecosystems. They are also a useful reference for establishing limits of acceptable change for ecosystem components and processes (Morgan et al. 1994). Desired conditions are not intended to re-create specific conditions, but rather to guide realistic management goals and objectives towards the development and maintenance of ecologically resilient ecosystems that provide for social objectives in a sustainable manner. The full range of historic variability is likely to include extreme conditions that are neither typical, resilient, nor desired.

Spatial Scale

Scale provides a breadth of focus for applying desired conditions and then monitoring and assessment of ecosystem indicators (USDA Forest Service 1989). Desired conditions stipulated at the watershed scale (multiple 6th-level units), for instance, indicate the average conditions for which to guide management when considered at the watershed scale. There may still be considerable variation at the subwatershed or reach scales within a watershed unit, but the focus for restoring or maintaining desired conditions involves the collective conditions across the given unit as a whole. Likewise when desired conditions are stipulated at the subwatershed or fine scales, achievement, monitoring, and assessment are focused at each given subwatershed or fine-scale unit.

The National Hydrologic Unit (HU) is the basis for defining the specific scales at which the desired conditions apply. The three scales most relevant to the implementation of desired conditions are:

- Watershed – Multiple 12-digit (6th-level) HUs within one to few subbasins (4th-level). A watershed comprising multiple subwatersheds of similar biophysical conditions and proximity,

such as would occur within a broader HU unit. The area included for a given analysis should exceed 1,000ac (400ha).

- Subwatershed – Groups of one to few 12-digit (6th-level). The subwatershed scale is composed of assemblages of fine-scale units.
- Fine – Areas *within* one 12-digit (6th-level) HU including individual reaches and riparian plant communities

Desired condition descriptions at these scales provide adequate detail and guidance for the design of projects and activities to help achieve desired conditions over time. Descriptions begin with the watershed scale to provide a “big picture” of the desired conditions across the larger land area. Descriptions at the subwatershed scale gives additional detail necessary for guiding future projects and activities. Fine-scale description is often reserved for project and prescriptive management phases. In this guide, fine-scale description is restricted to wetlands given their very limited extent, ecological importance, ubiquitous degradation and loss, and given the degree of site-level data collection and assessment involved.

Ecosystem Indicators

The indicators included here are applied collectively in planning and project design to describe desired conditions, and in assessment and monitoring to assess existing conditions and trends relative to desired conditions. While only one socioeconomic indicator is included here (ecosystem services-outdoor recreation), the assumption is that restoring and maintaining ecological integrity, as gauged through the monitoring and assessment of ecological indicators, will allow for the long-term delivery of services to human communities.

The assessment of existing conditions and descriptions of desired conditions should include a minimum set of indicators representing the four pillars – structure, composition, process, and connectivity (*FSH 1909.12, CHAP. 40, SEC. 43.12*) – with some indicators that also address ecosystem stress and water availability. Ecosystem indicators augment the synchrony among key phases of resource management – project planning, National Environmental Policy Act (NEPA) analysis, monitoring, and assessment and need for change.

Together indicators of structure, composition, process, connectivity, and stress serve as indicators of overall ecological integrity and are not meant to replace precise characteristics used for specific goals and objectives (e.g., corridor areas identified for particular species). Conversely, more precise characteristics cannot replace overall ecosystem indicators (e.g., invasive species cover is not a surrogate for overall plant composition).

The ecosystem indicators included with this guide reflect broad themes of ecological integrity that meet basic criteria for indicators (e.g., Hamilton et al. 2011):

- Consistent with regional conventions, data sources, and existing strategic plans
- Quantifiable and practical
- Support business needs of resource managers
- Meaningful for both strategy and projects
- Inform assessments that can be readily interpreted by practitioners and partners

Most indicators included with this guide can be applied with the Watershed Condition Classification (WCC; Potyondy and Geier 2011) as noted in the summary tables that follow.

Information on ecosystem indicators are included in the following descriptions for **riparian**, **aquatic** and **stressors**, and in the summary tables that follow those sections of the document. **The tables provide a quick reference for each ecosystem indicator** on analysis scale, rationale and references, data sources for existing condition, and quantitative desired conditions from which to calculate departure and trends.



Photo by FJ Triepke: Little Walnut-Chinkapin Oak map unit, Guadalupe Mountains, Lincoln National Forest, New Mexico.

Riparian Desired Conditions

Riparian ecosystems occur within all life zones. Riparian and wetland ecosystem types, or Ecological Response Units (ERUs), are differentiated from upland ecosystems by their site potential and ability to support wetland vegetation, by the historic disturbance regimes that included flooding, and by the successional patterns which are characteristic of riparian and wetland ecosystems (Wahlberg et al. 2019). Riparian corridor mapping is represented by the RMAP, and is made up of 25 ERUs and 11 subclasses (listed below). Detailed descriptions of each ERU and subclass are available in the RMAP project report 1.

Riparian Ecological Response Units and Codes

Desert Willow Group

Desert Willow (130)
Oak / Desert Willow (250)
Little Walnut / Desert Willow (360)

Cottonwood Group

Cottonwood / Hackberry (160)
Fremont Cottonwood – Oak (170)
Fremont Cottonwood / Shrub (180)
Narrowleaf Cottonwood / Shrub (230)
Rio Grande Cottonwood / Shrub (260)
Sycamore - Fremont Cottonwood (270)
Elm - Eastern Cottonwood (310)
Eastern Cottonwood / Shrub (320)

Historic

Historic Rip – Agriculture (400)
Historic Rip – Residential/Urban (410)
Historic Rip – Natural/Semi-Natural (420)

Riparian ERU Subclasses and Codes

Wetland

Alkali Herbaceous Wetland (playa)(7, play)
Herbaceous Wetland, Upper (10, uppr)
Herbaceous Wetland, Mid (11, mid)
Herbaceous Wetland, Lower Mild (12, lwrm)
Herbaceous Wetland, Lower Cold (13, lwrc)
Herbaceous Wetland, Great Plains (14, grpl)

Cottonwood-Evergreen Tree Group

Fremont Cottonwood – Conifer (150)
Narrowleaf Cottonwood – Spruce (240)

Montane-Conifer Willow Group

Arizona Alder – Willow (110)
Upper Montane Conifer / Willow (280)
Willow - Thinleaf Alder (290)

Walnut-Evergreen Tree Group

Little Walnut - Chinkapin Oak (210)
Arizona Walnut (300)
Ponderosa Pine / Willow (350)
Little Walnut - Ponderosa Pine (370)

Wetland

Herbaceous Wetland (190)
Shrub Wetland (140)*

Riparian / Wetland

Russian Olive* (5, oliv)
Mesquite Bosque (6, mesq)
Upland Wet Meadow* (4, mead)
Tamarisk (8, tamx)
Constructed Riparian (9, cnst)

*** - Provisional unit not included in mapping for ERUv5**

1 – (<https://www.fs.usda.gov/detailfull/r3/landmanagement/gis/?cid=stelprdb5201889&width=full>) TRIEPKE, F.J., M.M. WAHLBERG, D.C. CRESS, AND R.L. BENTON. 2019. RMAP – REGIONAL RIPARIAN MAPPING PROJECT. USDA FOREST SERVICE PROJECT REPORT AVAILABLE ONLINE. 53 PP.

****RMAP PROVIDES DETAILED DESCRIPTIONS OF ALL THE ERU TYPE CLASSES AND SUBCLASSES.**

The classification, mapping, and description of riparian and wetland ERUs will continue changing with new information. For the most part ERUs represent groupings of TEUI units (USDA Forest Service 1986) and TEUI information is embedded in the ERU map data for the region (www.fs.usda.gov/detailfull/r3/landmanagement/gis). Riparian ERUs can be organized roughly by life zone and geography:

- Upper – RMAP units 110, 230, 240, 280, and 290 are concentrated in the mixed conifer and spruce-fir life zones
- Mid – RMAP units 160, 210, 300, and 350* are concentrated in the woodland and ponderosa pine life zones across areas of both cold and mild temperature regime
- Lower, mild – RMAP units 130, 150, 170, 180, 250, 260, 270, and 360 are concentrated in desert and grassland life zones across areas of mild temperature regime
- Lower, cold – RMAP units 280, 350*, and 370 are concentrated in grassland and woodland life zones across areas of cold temperature regime
- Great Plains – RMAP units 310 and 320 occur in the Great Plains of eastern New Mexico and in the National Grasslands extending to western Oklahoma

* - Occurs in more than one type

Individual riparian ERUs are described in the RMAP report appendix (Triepeke et al. 2018).

Watershed-Scale Desired Conditions

Riparian and aquatic ecosystems support the distribution, diversity, and complexity of watershed and watershed-scale features that in turn support species, populations, and communities. The system's ability to support unique physical and biological attributes and the diversity of associated species (e.g., shrews and voles) is sustained by necessary soil, hydrologic regime, vegetation, and water characteristics.

Riparian areas are resilient to a variety of disturbances including fire, flooding, and animal and human use. Compared to surrounding uplands, riparian corridors may have reduced fire frequency and severity (Dwire et al. 2016; Everett et al. 2003; Skinner 2003) owing to characteristics such as surface water and saturated soils (Fire Regime V(III); Crane 1989; Pavek 1993; Tesky 1992; Uchytal 1989). Fire is infrequent and patchy, and riparian corridors are resilient and able to recover following fire where hydrologic processes have not been compromised. Regeneration, growth, and persistence of obligate vegetation is ensured by natural variation in depth to groundwater, volume of surface water, and timing and the magnitude of their fluctuations (Auchincloss et al. 2013; Horton et al. 2001; Smith et al. 2018; Stromberg et al. 1997). Flooding occurs at a frequency and magnitude characteristic of the watershed. Reference conditions for a given watershed can be determined using equations from Table 2 of 'Analysis of the Magnitude and Frequency of Peak

Discharge and Maximum Observed Peak Discharge in New Mexico and Surrounding Areas' (Waltemeyer 2008). The natural disturbance regime of a riparian ecosystem promotes a diverse plant structure consisting of herbaceous, shrub and tree species of all ages and size classes necessary for the recruitment of riparian-dependent species. Flooding and scour occur at a frequency and magnitude that at least supports the regeneration of riparian dependent vegetation that is common to each ERU (Glenn et al. 2017). Woody vegetation and high levels of structural and compositional diversity provide food, cover, and water for wildlife including terrestrial and aquatic invertebrates and vertebrates.

Riparian ERUs have sufficient structural diversity to support high bird species diversity and abundance with nesting and foraging opportunities for neotropical migrant birds, raptors, and cavity-dependent wildlife. The density and structure of vegetation provides site-appropriate shade to regulate water temperature in streams. All age classes are present for ERUs dominated by cottonwood, elm, willow, ash, alder and other phreatophyte trees. Seral state proportions (per the Southwestern Region Seral State Proportions Supplement 1) are applied at the watershed scale, where contributions from all seral stages and low overall departure from reference proportions are positive indications of ecosystem condition (seral stage percentages represent the approximate mid-point expressed in desired conditions and are used primarily to compute overall ecosystem departure).

Shrub cover is variable and depends on site potential for given TEUI units or as determined through field reconnaissance of reference sites (USDA Forest Service 1986). Herbaceous vegetation and other ground cover is present to filter sediments, stabilize streambanks, mitigate effects of flooding, and contribute to infiltration and groundwater recharge. At the watershed scale, overall plant composition similarity to site potential (FSH 2090.11) averages greater than 66% for either ecological status or functional group diversity, but can vary considerably at the subwatershed and fine scales owing to disturbance history and the diversity of seral conditions.

Spatial connectivity is provided within or between watersheds and, where appropriate, riparian ecosystems provide connectivity important for dispersal, access to new habitats, perpetuation of genetic diversity as well as nesting and foraging for special status species. Within riparian ecosystems connectivity is exhibited between and within aquatic, riparian, and upland components that reflect their natural linkages and range of variability. Less than 15% of riparian corridors are fragmented by roads or other human disturbances (Muldavin et al., 2011) with exceptions for fish barriers and water rights diversions. Lateral, longitudinal and drainage network connections include floodplains, wetlands, upslope areas, headwater tributaries, and intact habitat refugia. These network connections provide chemically and physically unobstructed routes to areas critical

1 (<http://fsweb.r3.fs.fed.us/eap/nfma/working-group/products/desired-conditions/index.shtml>) Southwestern Region Seral State Proportions Supplement

for fulfilling life history requirements of aquatic, riparian-dependent, and many upland species of plants and animals.

Subwatershed-Scale Desired Conditions

A diverse vegetation structure, including mature trees, snags, logs, and coarse woody debris, is present to provide habitat for riparian-dependent species. The species composition and structural diversity of native plant communities in riparian areas and wetlands provide adequate summer and winter thermal regulation, nutrient filtering, appropriate rates of surface erosion, bank erosion, and channel migration. The amount, spatial distributions, and sizes of CWD and fine particulate organic matter is sufficient to sustain physical complexity and stability.

The composition, structure, and function of vegetation conditions are resilient to the frequency, extent, and severity of disturbances and climate variability. Floodplains and adjacent upland areas provide diverse habitat components (e.g., vegetation, debris, logs) as necessary for migration, hibernation and brumation (extended inactivity) specific to the needs of riparian-obligate species (e.g., New Mexico meadow jumping mouse, Arizona montane vole, narrow-headed gartersnake). Riparian ERUs that have a strong tree component (Cottonwood Group, Cottonwood-Evergreen Tree Group, Montane-Conifer Willow Group) include large trees and snags to support species such as beaver, yellow-billed cuckoo, bald eagles, Arizona gray squirrel, and various bat species. Riparian woody regeneration is sustainable, approximating reference conditions according to the overall percentage of early-mid seral states (low departure). Lentic riparian areas (e.g., herbaceous wetlands, wet meadows, fens) have vegetation and landform present to dissipate wind action, wave action, and overland flow from uplands.

Riparian vegetation consists mostly of native species that support a wide range of vertebrate and invertebrate species; invasive plant and animal species are rare or absent. Ground cover comprising shrubs, perennial grasses, and forbs with basal vegetation values ranging between about 5 to 30% depending on site potential for a given TEUI unit or as determined through field reconnaissance of reference sites (USDA Forest Service 1986), while the amount of bare ground likewise reflects site potential (low departure). Native obligate wetland species dominate bank cover. Upland, dry-site vegetation is not increasing and the extent of riparian communities is widening or has achieved its potential and is within the natural range of variability. The amount of CWD (= large woody debris) is similar to reference condition of the given ERU (low departure) and is adequately recruited to sustain replacement. In lieu of more precise information, desired conditions for CWD over 12" diameter and 35' in length is 30 or more pieces per mile (>18 pieces per km, >30cm diameter, >10m long), OR for CWD over 6" diameter and 3' in length is 48 or more pieces per mile (>30 pieces per km, >15cm diameter, >1m long) for proper functioning condition (Stacey et al. 2006, USDA Forest Service 2003).

Riparian areas are capable of filtering sediment and aiding floodplain development that contribute to water retention and groundwater recharge. The ability of soil to be infiltrated by water, recycle nutrients, and resist erosion is maintained and allows for burrowing by particular at-risk species. Soil infiltration is satisfactory (USDA Forest Service 2020). These key processes and conditions, along with slope stability and associated vegetative root strength, wood delivery to streams, input of leaf and organic matter to aquatic and terrestrial systems, solar shading, microclimate, and water quality are operating consistently with natural disturbance regimes.

Fine-Scale Desired Conditions—Wetlands and Groundwater Dependent Ecosystems

Overall wetland condition reflects scores of ‘A’ or ‘B’ or an equivalent rating for proper functioning condition (BLM 2015; Faber-Langendoen et al. 2012; Muldavin et al. 2017; Prichard et al. 2003). Obligate species within wet meadows, around springs and seeps, along stream banks, and active floodplains provide sufficient vegetative ground cover (herbaceous vegetation, litter, and woody riparian species) to protect and enrich soils, trap sediment, mitigate flood energy, stabilize stream banks, and provide for wildlife and plant needs. Native plant and animal species that require wetland habitats have healthy populations within the natural constraints of the particular wetland community. Wetland ground cover and species composition (richness and diversity) is indicative of site potential (USDA Forest Service 1986) with vegetation comprised mostly of sedges, rushes, and perennial grasses and forbs. Invasive species are rare or absent. Overall plant composition similarity to site potential (FSH 2090.11) is greater than 66%, while basal vegetation values range between about 5 and 40% depending on site potential. The amount of bare ground likewise reflects site potential (low departure). Shrub cover is often low. Wetlands with the potential for shrub cover contain a diversity of age classes (>2), and where wetlands are integrated in riparian corridors, shrub are often concentrated along stream banks. Over time the spatial extent of wetlands is maintained.

Riparian Ecosystem Indicator Summary

Ecosystem Indicator	Lowermost Scale of Analysis	Rationale/References	Existing Condition Information Source	Desired Condition
Flood regime (frequency, duration, and magnitude)	Watershed	Environmental flows, and high flows in particular, support riparian vegetation by the germination and establishment of phreatophyte trees, recharging alluvial aquifers to support existing vegetation, and washing salts from floodplains and river banks to favor native trees over salt-tolerant invasives (Glenn et al. 2017; Yanoff and Bradley 2009a). In the absence of flooding, woody regeneration is likely to stem from secondary disturbances such as fire.	Stream gauge data; NHD hydrography; and anecdotal information on flow characteristics.	Reference conditions are sometimes available from historic stream gauge data. Reference conditions for a given watershed can be determined using equations from Table 2 of Waltemeyer (2008). Results from Glenn et al. (2017) identify minimum flood regime values necessary for sustaining ecosystem processes in the Southwest.
Fire regime (frequency and severity) <i>WCC indicator 8</i>	Watershed	Common indicator in assessments of the western US including, LANDFIRE FRCC, was applied as an ecosystem characteristic with most forest plan revision assessments (e.g., Barrett et al. 2010; DeMeo et al. 2015; Forbis et al. 2007; Friedrichsen et al. 2005; Ganguli et al. 2011; Haufler et al. 1999; Joyce and Heitschmidt 2003; Morgan et al. 1994; Noss 1990).	Current R3 fire regime summary (R3 current fire regimes and annualized probabilities JUNE 2016.xlsx; Monitoring Trends in Burn Severity mapping (Eidenshink et al. 2007)).	Riparian areas have reduced fire frequency and severity owing to characteristics such as surface water and saturated soils. Fire is infrequent and patchy, and riparian areas are resilient and able to recover following fire. Desired condition is low departure from historic fire regime (i.e., 0-33% similarity to reference condition, fire regime V(III); LANDFIRE departure formula).

Ecosystem Indicator	Lowermost Scale of Analysis	Rationale/References	Existing Condition Information Source	Desired Condition
Ecological status OR functional group diversity <i>WCC indicators 5 and 10</i>	Watershed for riparian ecosystems Subwatershed/ fine for wetland ecosystems	Common indicator in other assessments including the guide formally known as the R3 Allotment Analysis Handbook (FSH 2209.21), and one of the few indicators available and applied to evaluate the integrity of plant composition was applied as an ecosystem characteristic in about half of all R3 Forest plan revision assessments (Burton et al. 2011; Hamilton et al. 2011; O'Brien et al. 2003; Pellant et al. 2005; Pyke et al. 2002; Smith et al. 2017; USDA Forest Service 1989; USDA Forest Service 1997; WAAEDS 2012; Weixelman et al. 1999; Winward 2000). Functional group diversity or 'riparian vegetation percent of potential' can be used as surrogate indicators when information on existing or reference conditions is not adequate for assessment.	Plot data from FIA, Natural Heritage NM, NRCS NRI, recent TEUI, VegBank. The availability and quality of vegetation data may suggest that a more general measure is needed, such as <i>functional group diversity</i> .	Overall plant composition similarity to site potential (FSH 2090.11) is greater than 66%, with the calculation for of similarity based on USDA Forest Service (1997) and an area-weighted summary for ecological units within an analysis area
Seral state diversity <i>WCC indicators 5 and 10</i>	Watershed	Common indicator in ecological assessments in the US including LANDFIRE FRCC (Barrett et al. 2010; O'Brien et al. 2003; TNC,2006; Ullsten et al. 2005). Was applied as an ecosystem characteristic with all Forest Plan revision assessments.	Riparian Existing Vegetation mapping (REV)	Low departure from desired conditions, all seral states collectively (see R3 Seral State Proportions Supplement) using LANDFIRE departure formula (Barrett et al., 2010)
Riparian corridor connectivity <i>WCC indicator 3, attribute 1</i>	Watershed	This indicator accounts for connectivity versus fragmentation within riparian extents, with an emphasis on detecting intervening obstructions that might inhibit wildlife movement, fragment plant populations, or disrupt ecosystem processes (Muldavin et al. 2011). The indicator is similar to that of New Mexico's NMRAM and other protocols (Collins et al. 2008; Faber-Langendoen et al. 2008a, 2008b, 2009; Muldavin et al. 2011; McIntyre and Hobbs 1999).	Combination of spatial data including RMAP, Riparian Existing Vegetation (REV), and road layer	Low departure. Less than 15% of riparian corridors are fragmented by roads or other human disturbances (NMRAM; Muldavin et al., 2011) with exceptions for fish barriers and water rights diversions. Fragmentation can be measured with interior-to-edge ratios or other suitable metrics (Imre 2006) where 0-33% similarity to reference condition represents low departure.

Ecosystem Indicator	Lowermost Scale of Analysis	Rationale/References	Existing Condition Information Source	Desired Condition
Riparian woody regeneration <i>WCC indicator 5</i>	Subwatershed	<p>An important indicator of sustainable regeneration of the native riparian woody component.</p> <p>This indicator is similar to the NMRAM 'Native Riparian Tree Regeneration' metric (Muldavin et al. 2011) but is based on reference conditions determined for early and mid-seral states that are dominated by woody vegetation less than 5m in height or 5" in diameter.</p>	Riparian Existing Vegetation mapping (REV); R3 Aquatic-Riparian Inventory (ARI)	Low departure from desired conditions for early and mid-seral states (see R3 Seral State Proportions Supplement)
Ground cover OR bare ground	Subwatershed for riparian ecosystems Subwatershed/ fine for wetland ecosystems	<p>Common indicator of range conditions (DeMeo et al. 2015; Forbis et al. 2007; Hamilton et al. 2011; Herrick et al. 2005; Maczko et al. 2004; Mitchell 2010; O'Brien et al. 2003; Patterson et al. 2014; Pellant et al. 2005; Printz et al. 2014; Pyke et al. 2002; Shinnemann et al. 2008; USDA Forest Service 1997), and one of the few indicators available and applied to evaluate the integrity of understory vegetation.</p> <p>Was applied as an ecosystem characteristic in about half of all R3 Forest plan revision assessments.</p>	Plot data from FIA, Natural Heritage NM, NRCS NRI, recent TEUI, VegBank. A remote sensing solution has been proposed for monitoring of bare ground.	Low departure (i.e., 0-33% similarity to reference condition; LANDFIRE departure formula) from site potential based on either basal vegetation or bare ground (USDA Forest Service, 1986), area-weighted for all ecological units within an analysis area.
Coarse woody debris <i>WCC indicator 3, attribute 2</i>	Subwatershed	<p>From Bragg et al. (2000): Monitoring and maintaining woody debris is important because of its influence on channel development (Ruediger and Ward 1996), sediment trapping and storage (Potts and Anderson 1990), oxygenation and turbulent mixing of water (Sedell et al. 1988), organic carbon and nutrient cycling (Gregory et al. 1991), and species habitat (House and Boehne 1987).</p>	Fuels transect and plot data from FIA, Natural Heritage NM, NRCS NRI, recent TEUI, and local administrative units. Recruitment may be estimated based on existing stand conditions (sensu Bragg et al. 2000).	<p>The desired abundance of coarse woody debris varies by the type of riparian and aquatic systems (Bragg 1997) and more research and synthesis are needed for the Southwest.</p> <p>The default desired condition value is >30 pieces per mile (>18/km), diameter >12" (>30cm), length >35' (>10m) OR >48 pieces per mile (>30/km), diameter >6" (>15cm), length >3' (>1m) for proper functioning condition (Stacey et al. 2006; USDA Forest Service 2003; USDA Forest Service 2015; USDA Forest Service 2016).</p>

Ecosystem Indicator	Lowermost Scale of Analysis	Rationale/References	Existing Condition Information Source	Desired Condition
Exotic woody species cover <i>WCC indicator 11</i>	Subwatershed/ fine	<p>Common indicator of riparian and range conditions in the western US (e.g., Joyce and Heitschmidt 2003; Muldavin et al. 2011; Patterson et al. 2014; Smith et al. 2018). Invasive, non-native species can have a significant impact on community diversity and function.</p> <p>High levels of invasive exotic species within a riparian plant community are a direct threat to maintaining wetland function and biodiversity (Stenquist 2000). Common indicator of riparian and range conditions.</p>	R3 Aquatic-Riparian Inventory (ARI); plot data from FIA, Natural Heritage NM, NRCS NRI, recent TEUI, VegBank	<1% total canopy cover of exotic woody vegetation (Muldavin et al. 2011)
Wetland condition rating <i>WCC indicator 5</i>	Subwatershed/ fine	<p>In general, monitoring data on Forest Service wetlands in the Southwest are limited, and qualitative site-level <i>assessments</i> such as NMRAM (Muldavin et al. 2017) and Proper Functioning Condition (Prichard et al. 2003) serve as important stop-gap exercises for determining overall wetland function at a given site and point in time.</p>	Assessment results from Natural Heritage NM and local administrative units.	Overall wetland condition score of 'A' or 'B' or equivalent rating for proper functioning condition (sensu Prichard et al. 2003)
Infiltration <i>WCC indicator 7, attribute 1</i>	Subwatershed	<p>Soil infiltration refers to the soil's ability to allow water movement into and through the soil profile, to temporarily store water and allow for uptake by plants and soil organisms for productivity and other ecosystem functions.</p> <p>Infiltration rates are a measure of how fast water enters the soil.</p>	TEUI, NRCS SSURGO, and field reconnaissance and assessment.	Satisfactory; infiltration class is very rapid to moderately rapid OR site measured infiltration rate is equal to infiltration rate measured in a reference area of the same ecological unit.



Photo: Mills Canyon, Kiowa National Grassland, New Mexico

Aquatic Desired Conditions

Aquatic ecosystems are functioning with all their components, processes, and conditions that result from endemic levels of disturbances (e.g., fluvial, fire, herbivory) to support the distribution, diversity, and complexity of watershed features that in turn support species, populations, and communities. Aquatic habitats provide for the distribution of conditions (e.g., bank stability, substrate size, pool depths and frequencies, channel morphology, large woody debris size, and frequency) similar to reference condition watersheds or to other ecologically-relevant benchmarks. These habitat features support self-sustaining populations of native and desired non-native aquatic and riparian-dependent plant and animal species, including species listed as threatened or endangered under the ESA. Associated riparian and wetland areas maintain water-related processes (e.g., hydrologic, hydraulic, geomorphic) and maintain the physical and biological community characteristics, functions, and processes. Water quality supports healthy riparian, aquatic, and wetland ecosystems and other state-designated beneficial uses of water. Water quality maintains the biological, physical, and chemical integrity of the system and benefits the survival, growth, reproduction, and migration of species composing aquatic and riparian communities. Ponding and channel characteristics provide habitat, water depth, water duration, and the temperatures necessary for maintaining populations of riparian-dependent species and for their dispersal. Streams and their adjacent floodplains are capable of filtering, processing, and storing sediment; aiding floodplain development; improving floodwater retention; and increasing groundwater recharge.

Watershed-Scale Desired Conditions

The composition, structure, and function of aquatic ecosystems are resilient to the frequency, extent, and severity of disturbances and climate variability. Streams and their adjacent floodplains are capable of filtering, processing, and storing sediment, aiding floodplain development, improving floodwater retention, and increasing groundwater recharge. Road networks pose a limited risk to riparian and aquatic resources, with less than 10% of watersheds having more than 0.25 road-stream intersections per square mile (Cederholm and Scarlett 1981; Rieman et al. 1997; Smith and Friggens 2017). Riparian corridors are longitudinally connected with less than 15% disruption (Muldavin et al. 2011) with exceptions for fish barriers and water rights diversions. Groundwater-dependent ecosystems are maintained in satisfactory condition and provide benefits to dependent species. Vegetation and root masses stabilize stream banks, islands, and shoreline features against the cutting action of water. Large coarse woody debris provides stability to riparian areas and stream bottoms lacking geologic control (e.g., bedrock) or geomorphic features (e.g., functioning floodplains, stream sinuosity, width:depth ratio).

Instream flows are sufficient to create and sustain riparian, aquatic, and wetland habitats and to retain patterns of sediment, heat, nutrient, and wood routing. Flow regimes and water elevations

in wetlands, seeps, springs, and other groundwater-dependent ecosystems likewise support the structure and function of those systems. The timing, magnitude, duration, and spatial distribution of high and low flows support the sustenance of affected riparian and aquatic biota, with sufficient overall flow volume critical to survival and reproduction of plants and animals (Smith et al. 2017). Flow volume is sufficient for reproduction success for native fishes, herps, and other dependent organisms. Less than 10% of subwatersheds have a canal/ditch (acequia) density of >0.25 per square mile (Smith and Friggens 2017).

High flows recharge surface water and groundwater, deliver nutrients, and provide for the successful germination and establishment of cottonwoods, willows, and other obligate vegetation (Baker 1990; Stromberg 1997). High flows create and maintain habitat diversity including gravel beds, pools, and side channels (Gorman and Stone 1999; Horan et al. 2000). Riparian and wetland areas have vegetation, landform, and/or large coarse woody debris to dissipate stream energy associated with high water flow. Ephemeral channels provide support to downstream subsurface flows, riparian vegetation, groundwater recharge, and do not contribute to downstream water quality degradation outside of the natural range of variation.

Subwatershed Desired Conditions

Longitudinal, lateral, and vertical connectivity is provided within and among watersheds with contiguous aquatic features. Flows in intermittent and ephemeral systems provide for connectivity between channel and floodplain across time, consistent with the range of variation of a given watershed. Stream ecosystems, including ephemeral watercourses, are not fragmented by infrastructure or development. Streams provide connectivity important for dispersal, access to new habitats, and perpetuation of genetic diversity indicative of special status species. Riparian areas are connected vertically and laterally with surface and subsurface flows as reflected in an average entrenchment ratio of more than 2.2 in montane systems, while trends in incision average stable-recovering or no incision evident (Muldavin et al. 2011; Prichard et al. 1998; Schumm et al. 1984). Stream alterations (such as culverts, water crossings, and diversion structures) do not exclude aquatic species from their historic habitat or restrict seasonal and opportunistic movements. Longitudinal barriers to movement may exist to protect native aquatic species from nonnative aquatic species or for agricultural diversions that allow fish passage. Riparian, stream, wetland, and spring ecosystems are not significantly fragmented by infrastructure or development (see Riparian Desired Conditions), and springs developments allow for flows that provide for sustenance of associated ecosystems. Riparian-aquatic systems have a rating of proper functioning condition (BLM 2015; Prichard et al. 1998, 2003) but can vary at the fine scale. There are no state-listed impaired or threatened water bodies (EPA 1996).

Sedimentation is a key component of floodplain and wetland dynamics. Rates of sedimentation are characteristic of the geomorphic and climatic setting (Lienkaemper and Swanson 1987), and sedimentation dynamics support the establishment of riparian vegetation, the conversion of lakes

and ponds into wet meadows and fens, and other processes typical to a given watershed (Smith and Friggens 2017). Rates of sedimentation are influenced by recreation and resource management, but the overall sediment regime (including the timing, volume, rate, and character of sediment input, storage, and transport) represents the conditions under which aquatic and riparian ecosystems evolved to support healthy watershed function. Sediment load in transport reflects an overall balance between scouring and deposition, and reflects equilibrium between the amount of sediment load being supplied to the system and the sediment load capacity of the system.

Fluvial processes provide for structural complexity of aquatic habitats involving the main channel, side channels, floodplain scour pools, and other floodplain features (Muldavin et al. 2011). Perennial and intermittent streams are in equilibrium, with stretches of fast moving and relatively shallow water (riffles) alternating with deeper and slower moving (pools) sections (Stacey et al. 2006). Medium-gradient reaches express a larger number of pools and riffles per unit distance in comparison to high and low gradient streams. The number, size, distribution, and quality of pools is characteristic of the range of variation for the watershed, with pool to riffle ratios of 1:1 generally considered optimum for cold-water systems, and limited or no runs in pool-riffle complexes especially at lower water. Depending on the stream type, other features such as oxbows, side channels, sand bars, and gravel/cobble bars, provide habitat for sustaining species diversity typical of the area, and support all life stages of each species. Representative conditions show that multiple side and/or backwater channels and a mix of new depositional surfaces are present in the channel and on the floodplain (e.g., point bars and wrack lines). Oxbows may also be present within an active floodplain.

Stream processes provide the physical, chemical, and hydrological conditions indicative of natural settings. Vegetation, in turn, helps to reduce damage from floods by stabilizing soil, trapping sediment, and dissipating flow energy (Hickin 1984). Riparian vegetation stabilizes stream banks and offers shading over stream water to maintain conditions required for the persistence of native aquatic biota. Instream cover habitat is made up of trees and shrubs that provide shade and overhanging structure for protection from predators and as a resource for nearby food, such as insects (Harrington and Born 2000; Kaufmann et al. 1999). The desired amount of stream cover may be inferred by reference conditions for mid and late seral states for a given riparian ERU. Boulders, cobbles, fallen trees and logs, and exposed roots also offer instream cover, with the type and amounts of cover varying by ERU.

Fine-Scale Desired Conditions—Cold/Upper Elevation ERUs

Stream banks are vegetated or stabilized by natural materials such as rock or woody debris, ensuring their integrity and stability for the protection and function of associated aquatic and riparian habitats (Muldavin et al. 2011). At least 80% of the stream bank surfaces are vegetated or stabilized by natural materials. A characteristic abundance and diversity of vegetation is

present to provide bank stability and reduce erosion, particularly during high flows when vegetation offers a roughness function (Geyer et al. 2000; Hickin 1984). Woody vegetation, at amounts reflecting low departure from site potential (USDA Forest Service 1986), is present to absorb energy from moving water to reduce erosion. Within a given reach all characteristic instream mesohabitat types are present

Aquatic Ecosystem Indicator Summary

Ecosystem Indicator	Lowermost Scale of Analysis	Rationale/References	Existing Condition Information Source	Desired Condition
<p>Road crossings OR Riparian corridor disruption <i>WCC indicator 6</i></p>	<p>Watershed</p>	<p>Road crossings can function as dispersal barriers to native fish and can degrade water quality through introduction of sediment (DRACTU 2016). Road crossings can also impact flow regimes by creating impervious surfaces that favor runoff instead of infiltration, and by converting groundwater to surface water at road cutbanks. Road development is commonly attributed to the loss of riparian habitat, and roads contribute to sediment loads in streams and prevent natural channel dynamics in floodplains (DRACTU 2016; Macfarlane et al. 2014). The number of road crossings per unit area provides a strong inference and objective measure of the overall impact of roads on aquatic and riparian resources (Smith and Friggens 2017).</p>	<p>For road crossings, data are summarized for NHDplus catchments from the USEPA National Aquatic Resource Surveys (www.epa.gov/national-aquatic-resource-surveys/streamcat). For riparian corridor disruption, RMAP is combined with a roads layer to determine percent disruption (Muldavin et al. 2011), and to determine reference and current conditions for interior-to-edge ratios.</p>	<p>At watershed scales road crossings do not add sediment to streams, limit water infiltration, or inhibit fish movement, with fewer than 10% of watersheds exhibiting more than 0.25 road-stream intersections per square mile (<0.1 intersection per square kilometer; Smith and Friggens 2017). With exceptions for fish barriers and water rights diversions, riparian corridors have less than 15% disruption and low departure for interior-to-edge ratios (see methods, Muldavin et al. 2011).</p>
<p>Diversions density <i>WCC indicator 6</i></p>	<p>Watershed</p>	<p>Surface flows can be reduced with modifications such as impoundments, diversions, and groundwater withdrawal. Surface flow diversions decrease flow volume, increase water temperature, and create barriers to dispersal (DRACTU 2016). The density of canals and ditches provides an indicator of surface flow diversions.</p>	<p>Downloadable data from the NHDplus website (www.horizon-systems.com/nhdplus/) and select flowlines from NHD hydrography to calculate canal-ditch density for each HUC12 watershed.</p>	<p>Flow regimes are within their range of natural variation in terms of volume and water temperature [MGT GUIDELINE: <10% of watersheds have more than 0.25 canal-ditches per square mile (>0.1 per square kilometer; Smith and Friggens 2017).]</p>

Ecosystem Indicator	Lowermost Scale of Analysis	Rationale/References	Existing Condition Information Source	Desired Condition
Floodplain hydrologic connectivity and channel dynamics <i>WCC indicator 3, attribute 3</i>	Subwatershed	<p>Hydrologic connectivity is an indicator of the relationship of the river channel to its floodplain at the bankfull stage. The adjoining floodplain is constructed by the river in the present climate and overflowed at times of high discharge (Dunne and Leopold 1978).</p> <p>The connectivity between the river and riverine wetlands formed on its floodplain supports ecologic function and plant and wildlife habitat diversity by promoting exchange of water, sediment, nutrients, and organic carbon (Collins et al. 2008).</p>	RACES, PFC, Rapid Assessment (Stacey et al. 2006), NMRAM, Aquatic-Riparian Inventory (ARI)	Average entrenchment ratio is >2.2 for montane systems (NMRAM; Muldavin et al. 2011)
Channel elevation stability, incision <i>WCC indicator 3, attribute 3</i>	Subwatershed	<p>Downcutting of a stream channel leads to a decrease in the channel bed elevation. Incision is often caused by a decrease in sediment supply and/or an increase in sediment transport capacity.</p> <p>A balance of incision and aggrading over time indicates vertical connection between riparian zones and surface and subsurface water.</p>	Aquatic-Riparian Inventory (ARI), RACES, PFC	Trends in incision average 'stable-recovering' or 'no incision evident' (Muldavin et al. 2011; Prichard et al. 1998; Schumm et al. 1984)
Stream sediment balance	Subwatershed	<p>If sediment load equals capacity, no net change in erosion and deposition is expected and a given stream system is in approximate balance [capacity = load = no net erosion/deposition].</p> <p>A watershed without sediment balance may indicate headcutting and incision upstream and aggradation downstream.</p> <p>One consequence of incision is having channels with no access to their floodplain and associated impacts to floodplain potential for riparian vegetation.</p>	Aquatic-Riparian Inventory (ARI), RACES, PFC	There is sediment balance at the watershed and subwatershed scales, as determined by assessment of the same stream types over time using repeat monitoring

Ecosystem Indicator	Lowermost Scale of Analysis	Rationale/References	Existing Condition Information Source	Desired Condition
Habitat diversity, instream (pool runs), substrate	Subwatershed	<p>Fish and aquatic invertebrate diversity and population health is related to habitat diversity (Stacey et al. 2006). Features such as oxbows, side channels, sand bars, gravel/cobble bars, riffles, and pools can provide habitat for different species or for the different life stages of a single species. Fish use pools, with reduced current velocity and deep water, to rest, feed and hide from predators. Many species use gravel-bottomed riffles to lay their eggs.</p> <p>The number, size, distribution, and quality of pools, and pool to riffle ratios indicate the quality of fish habitat, along with the availability and complexity of features outside of the main channel. Woody debris and other large structures promote the formation of instream habitat diversity.</p>	Rapid Assessment (Stacey et al. 2006), NMRAM	<p>NMRAM rating 4. Microtopographic complexity with multiple side and/or backwater channels and a mix of and new depositional surfaces in the channel and on the floodplain, e.g., point bars and wrack lines, respectively.</p> <p>Oxbows may be present within an active floodplain. The channel includes pool-riffle complexes with limited or no runs, especially at lower water.</p> <p>Additional features outside the main channel may include terraces, tributaries, and swales and may be compensatory to the overall rating. See NMRAM v1.1, Table 4.24, for a checklist of features (Muldavin et al. 2011).</p>
Stream cover of vegetation, overhanging WCC indicator 5	Subwatershed	<p>Instream cover provides habitat for aquatic organisms including food and space resting, hiding, and reproduction (Harrington and Born 2000; Kaufmann et al. 1999).</p> <p>Woody vegetation is important to fish as overhead cover from aerial predators and visual isolation from aquatic predators.</p> <p>Overhanging vegetation and downed logs are also important as a source of nutrients and carbon and trophic base for aquatic food chains (Rhodes and Hubert 1991).</p>	Aquatic-Riparian Inventory (ARI), Riparian Existing Vegetation mapping (REV)	<p>Desired conditions are represented by the proportion and canopy cover of woody vegetation for mid and late seral states for a given ERU. (More precise desired conditions can be determined from aerial photo interpretation of reference reaches.</p> <p>Research on optimal stream cover conditions are also available (e.g., https://oehha.ca.gov/media/downloads/ecotoxicology/document/instream20cover2015.pdf)</p>

Ecosystem Indicator	Lowermost Scale of Analysis	Rationale/References	Existing Condition Information Source	Desired Condition
Stream bank cover	Subwatershed/fine	<p>For upper elevation stream types the resistance of a stream bank to erosion is important to the integrity and stability of associated riverine wetlands (Muldavin et al. 2011).</p> <p>Stable stream banks support more woody and perennial vegetation that, in turn, provides more stable and healthy wetland communities.</p> <p>Sites with the potential for erosion and with unstable stream banks are likely suitable candidates for restoration.</p>	Aquatic-Riparian Inventory (ARI), Rapid Assessment (Stacey et al. 2006), NMRAM	<p>>80% of the stream bank surfaces are vegetated or stabilized by natural materials such as rock or woody debris (NMRAM; Muldavin et al. 2011).</p> <p>This indicator applies only to mid and upper elevation riparian ERU groups (CEG, WEG, and MCWG).</p>
Water quality condition <i>WCC indicator 1</i>	Subwatershed	<p>The water quality indicator is based on State listings of impaired watersheds according to section 303(d) of the Clean Water Act (EPA 1996), which represents a comprehensive public record of all impaired or threatened water bodies, regardless of cause (e.g., individual or multiple pollutants, thermal, or unknown).</p> <p>A water body is considered impaired when it does not attain the water quality standards needed to support its designated uses.</p> <p>Standards may be violated when established total maximum daily loads are exceeded.</p>	State listings for 303d impaired watersheds of Arizona, New Mexico, and Oklahoma.	No State-listed impaired or threatened water bodies.

Resilience of Aquatic and Riparian Systems

Riparian and aquatic ecosystems are resilient to the effects of climate change, drought, and other major stressors. Upland systems of the watershed are of high ecological integrity, favoring stream and groundwater resources and the adaptive capacity of aquatic and riparian habitats, and their ability to withstand changes in hydrology resulting from climate, drought, and anthropogenic influences (Sabo et al. 2010; Seager et al. 2013). The integrity and resilience of these ecosystems favors affected organisms by operating within the sensitivity and adaptive capacity of their life cycle traits, in terms of modifications to and suboptimal conditions of natural flow regimes, water temperatures, external cues, and other environmental attributes (Smith and Friggens 2017). Changes to groundwater and surface water dynamics, and the associated ecosystems and species, are within the capability of ecosystems to endure outside stressors and sustain function.

Ecosystem indicators aimed at stressors, including stream changes, water balance deficit, and ecosystem services-recreation, are resilient to stress at watershed scales and are within or trending towards desired conditions. Where streamflow remains unregulated, less than 10% of fish-bearing watersheds are affected by changing climate in comparison to streamflow under historic (pre-1990) conditions at subbasin scales. Likewise water balance deficit, reflected by the difference in potential and actual evapotranspiration, is in balance or surplus. Though shifts in recreation opportunities change with warmer temperatures and increased climate variability, the overall amount of recreation and visitor satisfaction experienced on National Forests and Grasslands is maintained or enhanced over time. The amount of *bare ground* and *exotic woody species cover*, addressed previously under riparian desired conditions, double as indicators of stress and are likewise within or trending towards their reference conditions

Resilience to Stressors Summary

Ecosystem Indicator	Lowest Scale of Analysis	Rationale/References	Existing Condition Information Source	Desired Condition
Stream changes, flow and temperature	Watershed	<p>A key indicator for aquatic systems that reflects the combined effects of changes in stream flow and temperature on aquatic habitat.</p> <p>Perennial flows are required by all fish species. Peak flows induce reproductive behavior of many fishes and provide instream habitat for spawning and facilitate reproduction and survival of riparian vegetation (USFWS 2002).</p> <p>In addition, stream temperatures influence spawning behavior, reproductive success, and adult survival of native fish (Pankhurst and Munday 2011).</p> <p>See Smith and Friggens (2017), Appendix 3, where index values are generated from the USGS Streamstats available online (https://water.usgs.gov/osw/streamstats/).</p>	<p>USGS stream gauge data; US Forest Service Western US Stream Flow Metric Dataset (Stream Flow Metric Dataset (https://www.fs.fed.us/rm/boise/AWAE/projects/modeled_stream_flow_metrics.shtml))</p>	<p><10% of fish-bearing watersheds affected (i.e., if either MAFC \geq 1, MSFC \geq 1, or MASTC results in loss of ideal temperatures for native fish) (Smith and Friggens 2017)</p>
Water balance deficit	Watershed	<p>An important indicator reflecting the difference between potential evapotranspiration (PET) and actual evapotranspiration that reflects the atmospheric demand for water via evaporation and transpiration from the land surface relative to the supply of water to satisfy that demand (Heath et al. 2015).</p>	<p>Deficit values are developed by combining ESRI surfaces for actual evapotranspiration (https://www.arcgis.com/home/item.html?id=31f7c3727abf42249a43fe8f25470af4) and potential evapotranspiration (http://www.arcgis.com/home/item.html?id=718429fe190648ad89729b45e37e0aa2)</p>	<p>No/minor change in deficit from historical deficit conditions (<33% departure/dissimilarity)</p>
Ecosystem services - outdoor recreation (aquatic and riparian)	Subbasin/watershed	<p>One of eleven climate indicators included in the collaborative vetting process of Heath et al. (2015). A simple indicator of the level of recreation use and visitor satisfaction on NFS lands.</p> <p>A changing climate infers that the amount of individual types of recreation may shift over time.</p>	<p>USDA Forest Service (2018b). National visitor use monitoring program. Washington, DC: U.S. Department of Agriculture, Forest Service, Recreation, Heritage and Wilderness Resources. (http://www.fs.fed.us/recreation/programs/nvum/ [Accessed October 2018].)</p>	<p>Overall level of outdoor recreation use and visitor satisfaction averages the same or increases over time</p>

Summary

This guide supplements the RAES by identifying desired conditions for aquatic and riparian ecosystems and by identifying some important data sources for determining existing conditions, for both strategic and project-level initiatives. The desired conditions were not written for individual species or localities for which more specific desired conditions may be needed from a fine filter approach. This guide represents a living document that will be updated with new information and direction.

Desired conditions were written from the perspectives of desirable functional processes (Medina et al. 1996) and of observable ecosystem features involving structure, composition, and connectivity (*FSH 1909.12, CHAP. 40, SEC. 43.12*) that can be monitored and measured over time to inform management. This guidance calls for a multi-scale approach to ensure application of the appropriate scale for a given desired condition and to inform proposed actions according to overall ecosystem conditions and trends. The guidance is consistent with a framework of planning, analysis, and monitoring formed during the revision of Forest Plans in the Southwestern Region, and now being implemented at the project level with the R3 Ecosystem Analysis Framework.

The application of desired conditions requires periodic monitoring of resource conditions along with the analysis of ecological integrity to determine the degree of departure from desired conditions and the ability of ecosystems to continue delivering services including plant and animal habitat, recreation, clean water, fuelwood and timber, recreation, forage for cattle, and other ecological and socioeconomic benefits. It's a matter of identifying riparian and aquatic ecosystems that are compromised or likely to be compromised in the future, what drivers or stressors are affecting integrity, and communicating evidence for purpose and need along with the most suitable passive or active management.

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