INTEGRATED WATER MANAGEMENT PLANNING IN THE COLORADO RIVER BASIN

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EXECUTIVE SUMMARY

In recent years, increasing numbers of stakeholders have been seeking to understand and meet environmental needs for water in addition to needs for irrigation, drinking water and industry. Integrated Water Management Planning provides one approach to accomplishing this. As defined by the Colorado Basin Roundtable, the primary purpose of an Integrated Water Management Plan (IWMP) is to identify ways to meet environmental flow needs along with the needs of agricultural, municipal, industrial and residential water users.

To facilitate IWMPs across the Colorado Basin, the Colorado Basin Roundtable (CBRT) commissioned a project to assemble tools, frameworks and datasets designed to 1) promote understanding of local needs or opportunities for integrated water management planning; 2) help structure planning efforts to ensure that environmental and recreational needs are evaluated along with agricultural, municipal, industrial, and residential needs; and 3) facilitate reporting of locally-generated planning outcomes in a form that enables straightforward synthesis and comparison of results between watersheds. The resulting project deliverables seek to build a foundation for conducting stakeholder-driven IWMPs in the mainstem Colorado River Basin in Colorado. In addition to guidance for implementing stepwise IWMP planning processes, the project developed the following tools:

- A set of **data dashboards** that enables users to explore existing and natural flows, water use and shortages, the degree of hydrologic alteration, water quality and water quality compliance issues across the basin.
- A **studies library** compiling past studies in the basin relevant to integrated water management planning.
- A set of **interactive maps** compiling data layers from numerous sources, including the Colorado Basin Implementation Plan, that show the locations of major water infrastructure and water quality issues.
- A **scoring matrix** for assessing the ecological integrity of streams and the degree to which they are successfully meeting the needs and desires of communities, including providing water for irrigation and domestic use (Figure ES-1).

SHIFTING EXPECTATIONS

River values, needs, and the importance of ecosystem goods and services are shifting as economies and demographics in the Colorado River Basin evolve.

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- A **spatial mapping layer** that delineates all major streams in the basin into stream mile units in order to facilitate collecting and reporting data in a way that is consistent across the basin.

This document details a stepwise planning process and explains how to use these tools and information to support the development of IWMPs. The data dashboards can be helpful in the process of initial data exploration. The studies library and interactive maps, in conjunction with the data dashboards, can speed the process of collecting data on existing conditions and identifying issues that require additional research. Use of the matrix, together with the spatial mapping layer, will result in a concise way of capturing ecosystem condition and the capacity for a river to deliver important services to communities (e.g. irrigation water, flood mitigation and recreational opportunities) across the length of a stream or stream reach considered by an IWMP.

The matrix organization aims to communicate the breadth of issues any given IWMP effort may address. Early in the process, it can be used to discover which conditions and services or which geographic areas are priorities among stakeholders—an important first step for defining specific planning objectives. This document provides basic definitions for each column header in the matrix and identifies a variety of tools and methodologies for assessing each one. Basic guidelines for assigning scores (or grades) are also presented. The data dashboards, studies library, maps, and spatial mapping layer are available at http://uppercoloradoriver.org/co-river-headwaters/data-dashboards/ Screenshots and descriptions of these tools can be found in Appendix B.

	Ecosystem Condition										Benefits to Local Communities															
SMiRF ID	**Ecological Integrity**	Flow Regime	Sediment Regime	Water Quality	Network Connectivity	Floodplain Hydrology	Riparian Vegetation	Stream Corridor Dynamics	Structural Complexity	Aquatic Biota	**Provisioning**	Agricultural Production	Drinking Water Supply	Industrial Processing	Hydropower Production	**Regulating and Maintenance**	Flood Regulation	Groundwater Recharge	Erosion Control	Pest Regulation	Regulatory Compliance	**Cultural**	Aesthetics and Intrinsic Values	Symbolic/Emblematic Species	Boating Recreation	Angling Recreation
1.1		1	2	1	0	0	2	3	2	1		1	4	0	1		1	2	3	2	1		1	1	1	2
1.2		2	3	2	2	3	3	4	1	1		2	2	3	2		2	3	4	1	1		2	2	2	4
1.3		4	3	3	3	1	3	5	3	2		3	3	1	4		4	3	5	3	2		4	2	4	5
2		4	2	4	2	3	2	2	2	2		4	5	3	4		4	2	2	2	2		4	2	4	5
3.1		4	4	4	3	5	4	3	5	3		4	1	5	3		4	4	3	5	3		3	2	3	1
3.2		1	1	1	0	0	1	1	2	1		1	4	0	1		1	1	1	2	1		1	0	1	2
4		3	2	3	4	2	2	1	5	4		3	4	2	3		3	2	1	5	4		3	2	3	2

FIGURE ES-1. EXAMPLE MATRIX FOR ORGANIZING AND PRESENTATION OF ASSESSMENT RESULTS. RESULTS ARE ORGANIZED AROUND GEOGRAPHIC PLANNING UNITS, ECOSYSTEM CONDITION, AND THE SERVICES RIVERS PROVIDE TO LOCAL COMMUNITIES. THE SMIRF ID DELINEATES A PARTICULAR STREAM SEGMENT AND THE COLOR-CODED NUMBERS REPRESENT THE RELATIVE CONDITION (FROM "POOR "TO "GOOD"), OF EACH COLUMN HEADER .

This document provides a simple organizational strategy to 1) facilitate data analysis and organization 2) visualize the human demands for water and the other services streams provide, such as recreational opportunities, alongside indicators of river ecosystem health and resilience, and 3) provides a common language for communicating about conditions and community expectations across the multiple reaches and sub-watersheds of the Colorado Basin.

By defining a common language for organizing and reporting IWMP efforts, the ideas presented here will make it possible to compare results across the Colorado River Basin and to monitor changing ecosystem conditions and community perspectives at these locations over time.

BACKGROUND

Values, needs, and expectations associated with rivers and water use are expanding as economies and demographics in the Colorado River Basin change. A growing chorus of stakeholders are expressing concerns about the environmental impacts of historical land use patterns, prospects for population growth, climate change, and continued development of a limited water supply. At the same time, historical uses of water (e.g. irrigated agriculture) remain important to the economies, aesthetics and social fabric of rural communities. Good planning is the first step towards optimizing land and water management to support both environmental values and community needs.

Attempting to manage streams to meet both environmental and human needs in the Colorado River Basin is not a new idea. Since 1988, the Upper Colorado River Endangered Fish Recovery Program has worked to improve habitat for four species of endangered fish in the Colorado River near Grand Junction without interfering with water development needs (www.coloradoriverrecovery.org). Through a combination of rigorous scientific inquiry and stakeholder negotiations, measures such as coordinated reservoir releases, irrigation infrastructure upgrades and floodplain re-engineering have had significant positive impacts on habitat, while often benefiting water users as well.

Upstream, the Upper Colorado River Wild and Scenic Stakeholder Group formed in 2007 and is working to "balance permanent protection of the Outstandingly Remarkable Values (ORV's), certainty for the stakeholders, water project yield, and flexibility for water users along the Upper Colorado River (www.upcowildandscenic.com)." The group's focus area is a 54 mile stretch of river from Glenwood Canyon upstream to Gore Canyon. This group's activities have included filing for instream flow rights, conducting recreational user surveys and extensive monitoring, and the development of a toolbox of potential cooperative measures to help protect ORV's.

Even farther upstream, Grand County commissioned a detailed Stream Management Plan in 2010 to define environmental flow needs and guide its negotiations with Denver Water and the Northern Water Conservancy District over mitigation for proposed increases in transmountain diversions. Restoration projects have since drawn funding from numerous sources. Local irrigators have played a leading role in developing projects, as have conservation organizations.

Addressing environmental and recreational needs alongside agricultural, municipal and industrial water needs received another boost in 2013, when the Colorado Water Conservation Board (CWCB) developed a Non-Consumptive Needs Toolbox. The toolbox was developed in response to a request from the Interbasin Compact Commission (IBCC)—a body representing the diversity of water interests from each basin Roundtable—to promote incorporation of non-consumptive needs into Roundtable Basin Implementation Plans (BIPs). The Toolbox supports non-consumptive (i.e. environmental and recreational) water use planning with basic information about the methodologies for characterizing flow needs and a decision tree for identifying management opportunities (Figure 1).

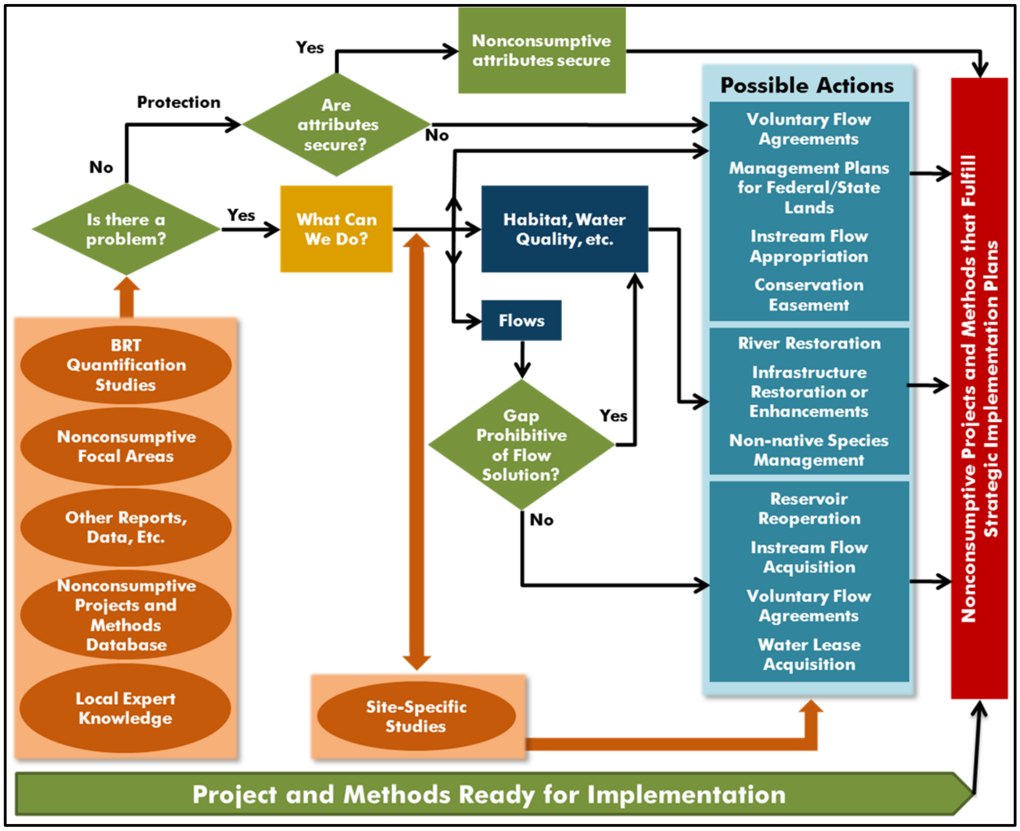


FIGURE 1. DECISION ANALYSIS APPROACH OUTLINED BY THE CWCB FOR NON-CONSUMPTIVE NEEDS ASSESSMENT AND ACTION IDENTIFICATION.

In many watersheds across the Colorado River basin there is insufficient data to effectively utilize tools like the Non-Consumptive Needs Toolbox decision tree to identify implementable actions. As a result, most non-consumptive use projects funded by the Colorado Basin Roundtable have been either vaguely defined or very narrow in scope.

The lack of non-consumptive water use planning across Colorado re-emerged as a prominent issue during the development of the 2016 Colorado Water Plan (CWP). Efforts by members of the Colorado Basin Roundtable and others led to the inclusion of an objective to promote Stream Management Planning. A new CWCB grant category for Stream Management Plans followed. In 2017, the CWCB described the basic components of Stream Management Planning efforts that could be funded through the Colorado Watershed Restoration program as:

> *"…grounded in the complex interplay of biology, hydrology, channel morphology, and alternative water use and management strategies. [SMPs] should also consider the flow and other structural or management conditions needed to support both recreational uses and ecosystem function. A stream management plan should (1) Involve stakeholders to ensure their acceptance of the plan; (2) assess existing biological, hydrological, and geomorphological conditions at a reach scale; (3) identify flows and other physical conditions needed to support environmental and recreational water uses; (4) incorporate environmental and recreational values and goals identified both locally and in a basin roundtable's BIP; and (5) identify and prioritize alternative management actions to achieve measurable progress toward maintaining or improving flow regime and other physical conditions."*

The Colorado Basin Roundtable has adopted the term "integrated water management planning" in place of "stream management planning." The CBRT defined the primary goal of an integrated water management plan (IWMP) as **identifying opportunities to meet environmental flow needs along with needs of agricultural, municipal, industrial, and residential water users.** The choice to use the term "integrated water management planning" was a response to concerns that "stream management planning" could emphasize environmental and recreational water needs in a way that might negatively impact agricultural water users and other interests.

Integrated water management planning is not a concept uniquely promoted by the CBRT. The concept has a history of development and refinement, as evidenced by a long list of scientific literature on the subject (e.g. Bouwer, 2000; Jønch-Clausen & Fugl, 2001; Medema et al., 2008; Mitchell, 2005; Rahaman & Varis, 2005; Pahl-Wostl et al., 2008; White, 1998). Many of the ideas presented by these authors and others are instructive for planning in the Colorado River basin. Integrated water management plans aim to guide water management to meet stakeholder needs in a way that supports healthy rivers and the services they provide to local communities.

In 2017, the CBRT requested the development of tools and information to aid in 1) understanding local needs or opportunities for integrated water management planning in a sub-basin or watershed context, 2) structuring planning efforts to assure environmental and recreational needs are evaluated along with agricultural, municipal, industrial, and residential needs, and 3) support reporting of local results to the CBRT in a form that eases synthesis and comparison between watersheds. The result was the organizational framework discussed in this document.

By defining a **common language** for organizing and reporting IWMP efforts, this framework makes it possible to compare results across the Colorado River Basin and to monitor changing ecosystem conditions and community perspectives at these locations through time. It is a high-level, scale-independent planning approach that accommodates diverse assessment methodologies, allowing flexibility in how locals advance planning and data-gathering exercises based on specific planning objectives, data limitations, etc. It aims to simplify the development of Requests for Proposals (RFPs) and Scopes of Work (SOWs) for future planning efforts. It may also prompt practitioners to design and implement more comprehensive and practicable integrated water management plans.

THE IWMP CONCEPTUAL MODEL

The conceptual model that guided the development of this document adapts aspects of several decision-making structures (Brukhard et al., 2012; Maes et al., 2016; Poff et al., 2010; Van Oudenhoven et al., 2012) to the specific needs of water management planning (Figure 2). The conceptual model contains three interconnected limbs that represent the core IWMP elements:

1. The need to evaluate alternative management actions is typically prompted by an observed or expected change in a stream's ability to provide goods and services, and the effects of alternative actions can be evaluated in terms of impacts to ecological condition.
2. The ability of a stream to provide important regulating, provisioning, and cultural goods and services depends on ecological condition.
3. Exploiting streams to make use of goods and services may alter the biophysical setting and prompt the need to evaluate alternatives.

Understanding the interaction between these three core elements is critical in developing a planning process that can anticipate cascading and/or synergistic ecological and socio-economic effects of changes in water management, shifts in climate, evolving ecosystems, etc. contemplated by IWMPs.

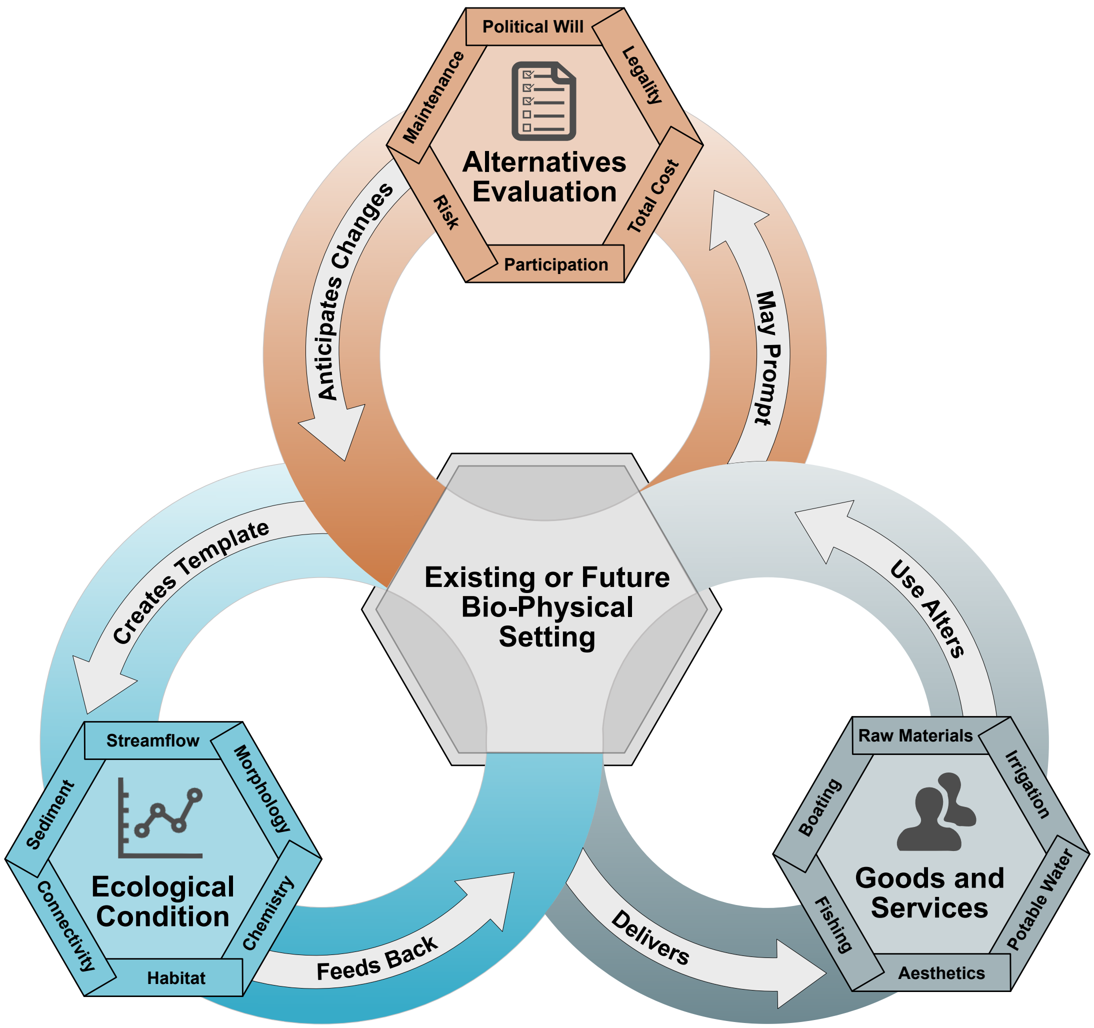


FIGURE 2. CONCEPTUAL MODEL FOR INTEGRATED WATER MANAGEMENT PLANNING IN THE COLORADO RIVER BASIN.

PLANNING PROCESS

Extension of the *Rational Planning Model* (Taylor, 1998) yields a structured approach to integrated water management planning (Figure 3) that accommodates the core elements of the IWMP conceptual model and a pathway for navigating the decision points in the Non-Consumptive Needs Assessment Toolbox decision tree. The process includes uniquely identifiable elements suitable for stepwise application of specific planning methods, tools, or techniques. It is also fully compatible with other established methodologies for characterizing environmental flows or evaluating non-consumptive use assessment like The Nature Conservancy's Savannah Process (Ward and Meadows, 2011), the Downstream Response to Imposed Flow Transformation (DRIFT) method (King et al., 2003), the Building Block Methodology (King and Louw, 1998), and the Ecological Indicators of Flow Alteration (Poff et al., 2010). Recently developed software tools like InVEST (www.naturalcapitalproject.org/invest) and ARIES (aries.integratedmodelling.org) may also be useful building and implementing the planning process.

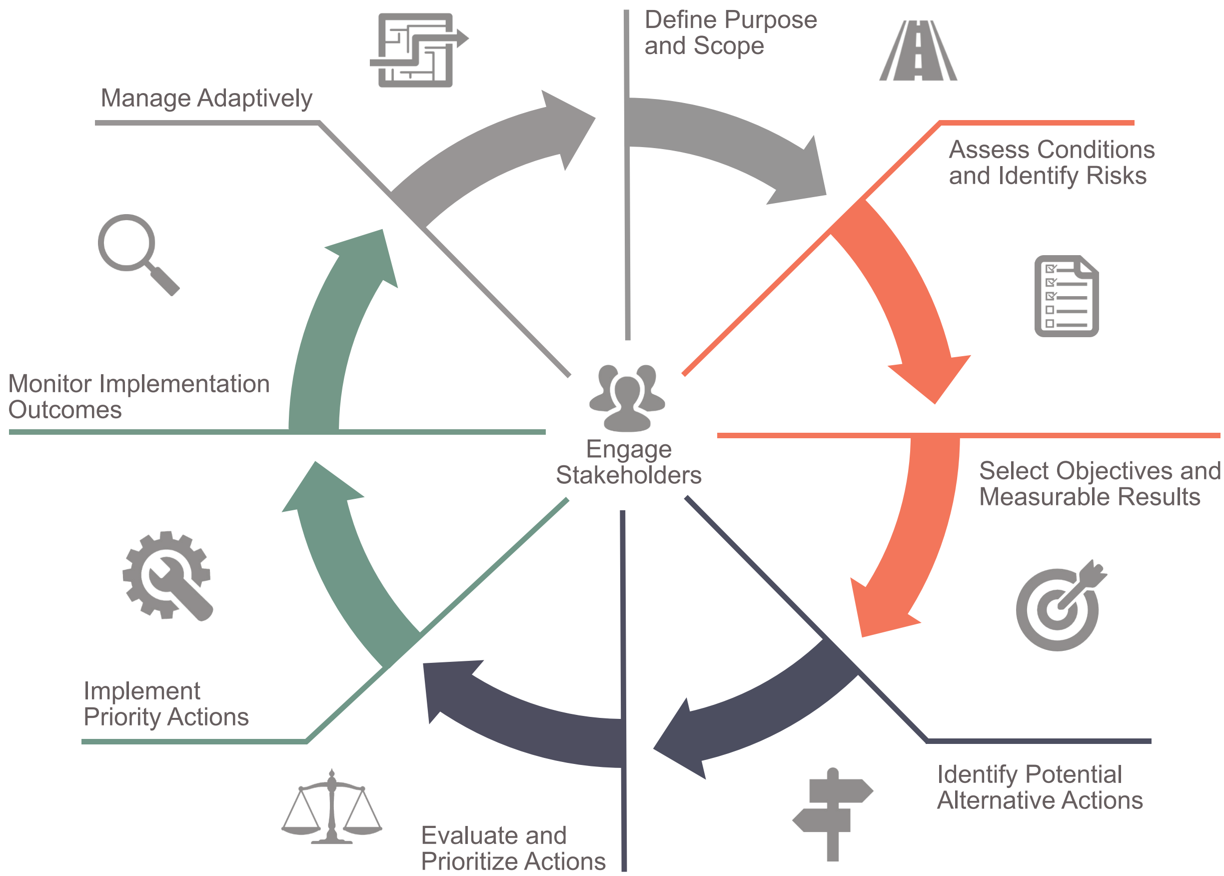


FIGURE 3. MODIFICATION OF THE RATIONAL PLANNING MODEL (TAYLOR, 1998) TO ACCOMMODATE THE UNIQUE NEEDS OF INTEGRATED WATER MANAGEMENT PLANNING ON COLORADO STREAMS AND RIVERS. MANY PLANNING EFFORTS WILL END WITH AN EFFORT TO EVALUATE AND PRIORITIZE MANAGEMENT ALTERNATIVES, WHILE SOME WILL GO ON TO IMPLEMENT AND MONITOR OUTCOMES OF SPECIFIC ACTIONS.

Each step presented below requires thoughtful design and execution and careful consideration of the need for stakeholder input. When applied well, the process is capable of guiding a stakeholder group and practitioners through iterative problem identification, goal setting, and implementation of preferred solutions. While the details and composition of each planning effort will reflect local needs and considerations, the generic planning stages presented in Figure 3 are likely to remain relatively consistent across efforts.

Step 1: Engage Stakeholders

Engaging stakeholders is central to every step of the planning process, including preliminary decision making about whether or not to pursue and IWMP. Since IWMP's contemplate potential changes to water management, it is vital to develop a solid understanding of current water management practices and their environmental and social importance prior to embarking on any planning effort.

Entities interested in pursuing an IWMP should first identify organizations, individuals and constituencies that have an interest in how the stream is managed and meet with as many of them as possible to identify what their interests are and what might make participation in an IWMP process worthwhile to them, as well as what people or organizations they may feel comfortable representing them, and what kinds of data they would consider important and credible to inform any planning effort. This will provide important information up front about whether sufficient stakeholder interest exists to engage in a planning effort and how to ensure that the process is credible, accessible and worthwhile for the people and organizations whose cooperation will be essential for the implementation of any resulting plan. It will also inform the definition of the purpose and scope of the effort, if it goes forward.

A local organization or institution with a history of engagement in water conservation, use and/or management is generally best suited to stakeholder engagement and outreach tasks. Existing stakeholder processes (e.g. Wild and Scenic stakeholder discussions, source water protection planning efforts, etc.) may also represent a useful venue for launching discussions about integrated water management planning.

Most planning processes will benefit from the development of a Stakeholder Outreach and Engagement Plan. This plan should detail the organizations and individuals that will participate in planning activities, the schedule for meetings and planning milestones, the methods that will be used for communication and information sharing, and the types of decision-making that stakeholders will be asked to participate in. In many cases, it will be necessary to collaboratively develop a set of Principals for Effective Communication. The Principals should be developed with stakeholders and used subsequently to guide group discussions. Facilitated dialog orchestrated by a professional mediator or facilitator may be necessary in contentious planning settings.

Step 2: Define Purpose and Scope

Defining the overarching planning purpose and scope is a critical early step in the process and requires some reflection on the foundational motivation—the catalyst—for planning. Recognizing the nature of the motivation for planning and reflecting on where that motivation intersects with the conceptual model presented previously should help stakeholders develop a clear purpose and scope for subsequent planning steps. In the Colorado River basin, motivation may come in a variety of forms but can likely be characterized as either anticipatory, reactionary, or exploratory in nature:

ANTICIPATORY PLANNING: GRAPLING WITH EXTERNALITES

These planning efforts respond to some expected change to the system that will impact current environmental and/or human uses. Examples include planning in advance of reservoir construction, changes in water rights ownership or administration, expected changes in reservoir operations, or climate change assessments.

The point of entry into the conceptual model (Figure 3) is in the anticipated changes to the bio-physical setting. Anticipatory planning efforts will often begin with a clear sense of the scope and scale of the change expected in the system. Such plans will likely focus on understanding potential impacts on ecosystem condition and the services the river provides to the local community. Where impacts are expected to be profound or undesirable, planning objectives will focus on minimizing those negative effects or on modifying the scope and scale of the action causing the negative changes.

A special case of Anticipatory planning deals with climate change. In these cases, the expected change is not due to a management action but, rather, to a shift in the fundamental character of the bio-physical setting itself. These planning efforts will often focus on understanding the risks to ecology and the services a river provides to a community that are associated with a range of possible future states.

REACTIONARY PLANNING: RESPONDING TO EXISTING CONDITIONS

Reactionary plans might respond to some significant local or regional event that brings attention to ecosystem condition or the ability of the river system to deliver important goods and services to local communities. Examples include Water Quality Control Division regulatory action that identifies water quality impairments; complete dewatering of streams during drought conditions; or extreme flooding events that damage infrastructure or change the course of a river. The point of entry into the conceptual model (Figure 3) is along the feedback loops between the bio-physical setting, ecological condition, and the delivery of goods and services. Reactionary planning efforts will likely begin with a clear understanding of some undesirable ecological condition or some imbalance between demand and delivery of services the community expects a river to provide. These planning efforts will focus considerable time and energy characterizing the relative feasibility and effectiveness of alternative actions that respond to the primary issue of concern.

EXPLORATORY PLANNING: JUST FISHING

Some planning may be implemented in an opportunistic manner in response to an enthusiastic stakeholder group or availability of funding. These plans may reflect a general sense that opportunity exists for improving stream conditions or a river's delivery of services to the community without any specific ideas about where or when that could occur. Exploratory planning efforts typically focus on broad surveys of existing ecological conditions and/or community preferences for the delivery of goods and services from the river. Identification of impaired or at risk ecological conditions or imbalances between demand and delivery of goods and services from the river may be the basis for discussions about more focused geographic areas, management objectives and alternative management strategies. Alternatively, these efforts may not proceed to the point where management actions are identified and prioritized at all. Instead, they may more closely resemble an approach to non-consumptive use assessment reflected by the State Water Supply Initiative (CWCB, 2010) and the Watershed Flow Evaluation Tool (Sanderson, et al., 2012). The expectation for planning outcomes in these cases is that they inform future plans and projects.

Step 3: Assess Conditions and Identify Risks

Integrated Water Management Planning should optimize water management for both non-consumptive and consumptive, ecological and human uses of water. It is critical that planning efforts are rooted in a robust understanding of physical conditions and ecological processes as well as constraints posed by human needs, including water rights and consumptive uses. At the very least, such planning processes should not increase risk to aspects of river health or uses of water that benefit local communities.

A wide variety of environmental flow assessment methodologies appear in the scientific literature and in common practice. Some approaches focus on aquatic species habitat, while others focus on water quality, riparian function, or geomorphic processes. While these methods are well-established, increasing numbers of scientists and practitioners point to the need for holistic characterizations that couch ecological assessment in concrete terms that are directly relevant to decision makers and planners. Integrated ecological and human values assessments are best suited to water resources planning and management. Explicit characterization of the relationship between ecological conditions and the services that communities receive from streams and rivers, such as agricultural irrigation and recreational opportunities, can help clarify tradeoffs and make the decision-making space more relevant and approachable for a diverse, non-technical audience. This section describes a flexible assessment framework and scoring matrix for characterizing ecological conditions and the benefits that local communities receive from streams and rivers.

DELINEATE PLANNING UNITS

Relatively homogenous planning units should be drawn within the project bounds. The specific scale for observation and reach delineation selected by a stakeholder group will reflect the purpose and scope of the project and the specific questions of interest. Units may be drawn at the watershed scale, the reach scale, or the channel scale (Figure 4). Bounds should generally correspond to changes in hydrological behavior, network structure (e.g. Strahler stream order), geomorphic characteristics (e.g. Brierley and Fryirs, 2013; Bledsoe and Carlson, 2010), dominant land use and land cover types, physiographic regions, or locations of important water management infrastructure (i.e. diversion points, reservoirs, etc.). The upstream and downstream bounds of each unit should be defined along the stream network. These planning units will provide the basis for organizing assessment results and reporting back to CBRT and other stakeholders.

To facilitate this task, this project developed a common spatial mapping data layer. The spatial data layer was developed by modifying the Colorado Decision Support System (CDSS) Source Water Routing Framework—a mapping and GIS data layer that delineates all major streams in the Colorado River basin into stream mile units—to include further segmentation of streams into 1/10th mile segments. The resulting Stream Mile Route Framework (SMiRF) is a fine resolution spatial mapping layer for the Colorado River basin equally suitable for demarcating study bounds according to geomorphic characteristics, physiographic regions, water management infrastructure, etc.

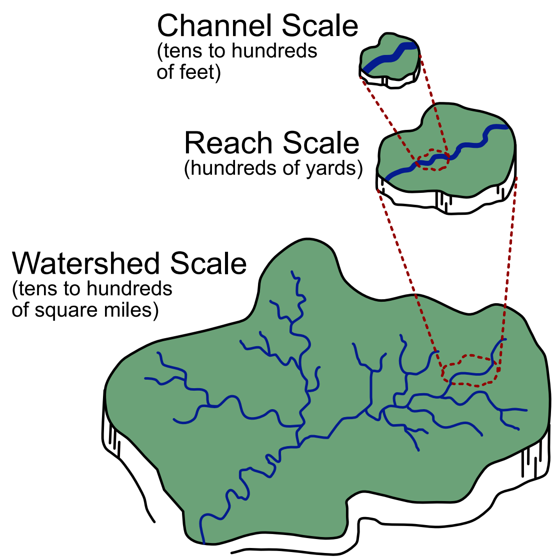


FIGURE 4. POTENTIAL NESTED SCALES FOR IWMP STREAM REACH AND PLANNING UNIT DELINEATION IN THE COLORADO RIVER BASIN

Use of SMiRF for delineations is also relatively scale-independent. A given planning unit delineated with SMiRF may cover reaches as short as 1/10th mile or may cover 100 miles or more of the mainstem Colorado. Planning units may also be organized into hierarchically nested structures. This may be useful where stakeholders or practitioners want to organize planning units as reaches containing sub-reaches, or as watersheds containing stream segments. Some basic regulatory and physiographic information that may be useful for delineation tasks is included in the SMiRF attribute table (Table 1). The SMiRF data layer is available for download from the Colorado Mesa Upper Colorado River Basin Resource Guide website: http://uppercoloradoriver.org/co-river-headwaters/data-dashboards/.

Demarcation of the top and bottom of a planning unit requires identification of the closest unique SMiRF ID ('smirf_ID' in Table 1) corresponding to those geographic positions within the stream network. All ID pairs should be recorded in table form (see Figure 5 and Appendix A). In cases where the selected planning unit includes an entire dendritic network and no single upstream location can be selected, users can record the downstream ID and mark the upstream ID with an Asterix (*). All planning unit delineations should be submitted to CBRT at the conclusion of the planning effort. Use of this common spatial mapping approach for delineating planning units will help communicate planning outcomes to outside groups and beyond the lifetime of a given planning effort.

TABLE 1. THE STREAM MILE ROUTE FRAMEWORK (SMIRF) ATTRIBUTE TABLE INCLUDES KEYS AND CODES (E.G. GNIS ID, NHD PERMENANT ID) THAT ALLOW IT TO BE LINKED TO A VARIETY OF WATER RESOURCE DATASETS. THE SMIRF ALSO INCLUDES PHYSIOGRAPHIC (E.G. COUNTY, HUC8) AND REGULATORY (E.G. REGULATION 93 SEGMENTATION) INFORMATION TO AID IN PLANNING UNIT DELINEATION FOR A GIVEN IWMP EFFORT.

Attribute	Description
smirf_ID	Unique identifier consisting of CWCB Source Water Route Framework (SWRF) Segment ID plus the distance upstream from the segment mouth in tenth-mile increments
seg_mi	The distance upstream from the mouth of the SWRF segment in miles.
seg_m	The distance upstream from the mouth of the SWRF segment in meters.
elev_m	Approximate elevation in meters, derived from 10m USGS DEM
swrf_ID	CWCB Source Water Route Framework ID
GNIS_ID	Geographic Names Information System ID, from USGS National Hydrology Dataset
GNIS_Name	Geographic Names Information System Name, from USGS National Hydrology Dataset
NCNAcomID	Common ID from SWSI-2010 Focus Segments and Nonconsumptive Needs Assessment (NCNA) mapping databases for NCNA focus area attribtues and projects
NCNAmapID	2010 Nonconsumptive Needs Assessment (NCNA) map ID
NHDpermID	USGS National Hydrology Dataset permanent ID
NHDreachCD	USGS National Hydrology Dataset reach code
Reg93geoID	Colorado Water Quality Control Commission (WQCC) Regulation 93 geo-ID
County	County name
WaterDistric	CDWR administrative district code
DistrictName	CDWR administrative district name
HUC8	Hydrologic Unit Code 8-digit (Subbasin) code identifier
HUC8Name	Hydrologic Unit Code 8-digit (Subbasin) name
HUC10	Hydrologic Unit Code 10-digit (Watershed) code identifier
HUC10Name	Hydrologic Unit Code 10-digit (Watershed) name
HUC12	Hydrologic Unit Code 12-digit (Subwatershed) code identifier
HUC12Name	Hydrologic Unit Code 12-digit (Subwatershed) name

Unit	Downstream ID	Upstream ID
Reach A	1.a	2.a
Reach B	1.a	3.a
Watershed C	1.a	*

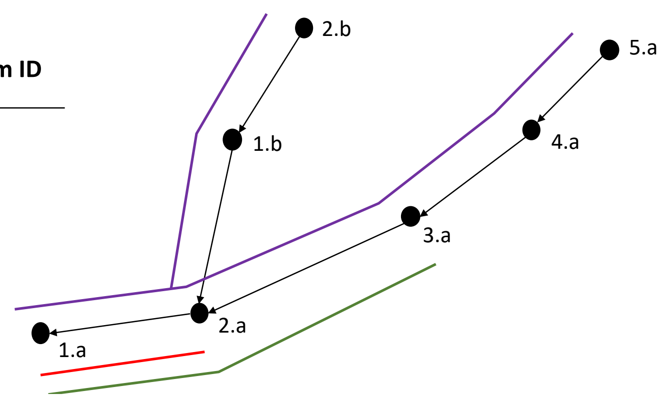


FIGURE 5. APPROACHES FOR DELINEATING PLANNING UNITS USING THE UNIQUE SMIRF ID ATTRIBUTE.

SELECT APPROACH FOR EVALUATING RISK OR IMPACT

The consideration of change, either natural or human-influenced, is at the core of integrated water management planning. The IWMP conceptual model acknowledges feedbacks between ecological condition and a river's capacity to deliver services such as irrigation, recreational opportunities and flood control to surrounding communities. Recognition of historical or future changes that may alter ecology or delivery of these services motivates investigation of alternative management actions. Characterization of the risk(s) associated with those changed conditions is, therefore, necessary for guiding stakeholders through reach and issue prioritization exercises. Anticipatory planning efforts may characterize risk by comparing existing conditions to some expected future state following a change in water demand, management, or climate. Conversely, reactionary planning efforts may focus on impacts that have already occurred through comparison of the existing condition to some natural or 'reference' condition. Development of consensus among stakeholders regarding risk or impact characterization strategies should simplify selection of appropriate approaches for ecological condition assessment and evaluation of how well a river is delivering expected services to communities.

CHARACTERIZE ECOLOGICAL CONDITIONS

Comprehensive evaluations that consider all the important aspects of stream health are the foundation for understanding existing ecological conditions and the environmental impacts of proposed actions. Multi-faceted approaches that integrate a suite of evaluation methodologies, while requiring more effort, are more adept at predicting secondary impacts that may not be recognized in narrowly focused assessment approaches that rely on prescribed methods. For example, many environmental flow assessments have focused on trout habitat impacts of depleted flows using simple models like R2Cross. Management recommendations based on these assessments alone neglect important connections between peak flows, sediment dynamics, and the processes that maintain physical habitat over the long term. These and other secondary impacts can be identified and planned for when assessment methods for multiple factors from an array of river subdisciplines are integrated into comprehensive evaluations.

WATERSHED-SCALE PROPERTIES AND FUNCTIONS

- Flow Regime
- Sediment Regime
- Water Quality
- Network Connectivity

REACH-SCALE PROPERTIES AND FUNCTIONS

- Floodplain hydrology
- Riparian vegetation
- Fluvial Geomorphology
- Structural complexity
- Aquatic biota

A comprehensive assessment of ecological conditions will help reduce the chance that planned actions produce unforeseen detrimental effects. FACStream (Beardsley et. al. 2015) and the River Health Assessment Framework (City of Fort Collins, 2015) were designed to integrate multiple river science perspectives to give a holistic view of stream health. Organizational approaches like these provide a formal structure useful for scientific assessments, ensuring that all important aspects of ecosystem function are considered.

At a minimum, assessments of historical, existing, or future ecological conditions completed within an IWMP in the Colorado River basin should consider the following: flow regime, sediment regime, water quality, network connectivity, floodplain hydrology, riparian vegetation, fluvial geomorphology, structural complexity, and aquatic biota. A definition and brief discussion of each assessment factor is provided in the subsections below. Assessments are made relevant to decision-making by identifying the dominant stressors, causes of impairment, and constraints on ecological integrity. This assessment framework does not prescribe which methodologies to use in evaluating each factor, but some considerations are provided below.
The methodologies selected for assessing each factor will depend on the scope and purpose of the planning effort, the scale of the planning area, and the budget available. The coarsest approaches (Level 1) produce qualitative, reconnaissance-level assessments that guide more targeted investigations. Rapid assessments (Level 2) focus on specific areas of concern and may involve more intensive ecological or social surveys. Intensive quantitative (Level 3) evaluations are more rigorous studies and use quantitative scientific methods to investigate issues of particular interest to a planning effort (Table 2, Figure 6). This tiered evaluation structure facilitates a "drill-down" investigative approach where results generated by each assessment level inform allocation of time, energy, and financial resources to investigation of the issues or attributes that are most important. This assessment approach is well-suited to evaluating ecological condition and for characterizing services that rivers provide to communities.

TABLE 2. EXAMPLE METHODOLOGIES FOR ASSING ECOSYSTEM CONDITION AND SERVICES RIVER PROVIDE TO COMMUNITIES THAT MAY BE EMPLOYED DURING DEVELOPMENT OF IWMPS.

Assessment Level	Description	Example Methodologies
Level 1	Coarsest level of investigation designed to provide a general estimation of ecological integrity or services rivers provide to communities.	• Anecdotal evidence, direct observations • Review of published literature and reports focused on streamflow, erosion, water quality, and aquatic life. • Aerial imagery assessments • "Windshield" surveys
Level 2	Domain scientists and other experts use best professional judgement to assess qualitative observations and data gathered during field visits.	• Rapid (1-2 day) functional condition assessments of stream reaches conducted by teams of geomorphologists, hydrologists, engineers and riparian ecologists • User preference surveys
Level 3	Quantitative methodologies that use data to generate numerical or statistical metrics of ecological condition or delivery of services rivers provide to communities.	• 1D/2D hydraulic modeling • Biological sampling • Riparian transects • Aquatic habitat surveying • 'Boatable days' analysis

This framework does not prescribe specific methodologies for assessing ecosystem condition or services rivers provide to local communities. However, it does provide standard organizational and reporting structures to more effectively communicate which methods were employed and the results they produced. Characterizations of each factor may be carried out using qualitative and/or quantitative investigations applied at a variety of scales. In some cases, qualitative expert opinions or desktop (e.g. GIS) assessments that quickly characterize conditions across large areas are sufficient. In other cases, intensive quantitative analyses and modeling exercised may be required to boost the level of confidence for planners and decision-makers.

Quantitative and repeatable approaches are preferred over subjective assessments for many factors because, in most cases, the IWMP exercise will involve comparison of baseline condition to predicted future conditions that are not immediately observable and must be tracked objectively over time. To maximize the utility of the work completed, a detailed description of the method(s) utilized to assess each indicator of ecological structure/process should be provided and mapped to the planning units where the method(s) were applied. The description should specify the data sources so the level of quality assurance and control can be taken into account. Example reporting worksheets are included in Appendix A.

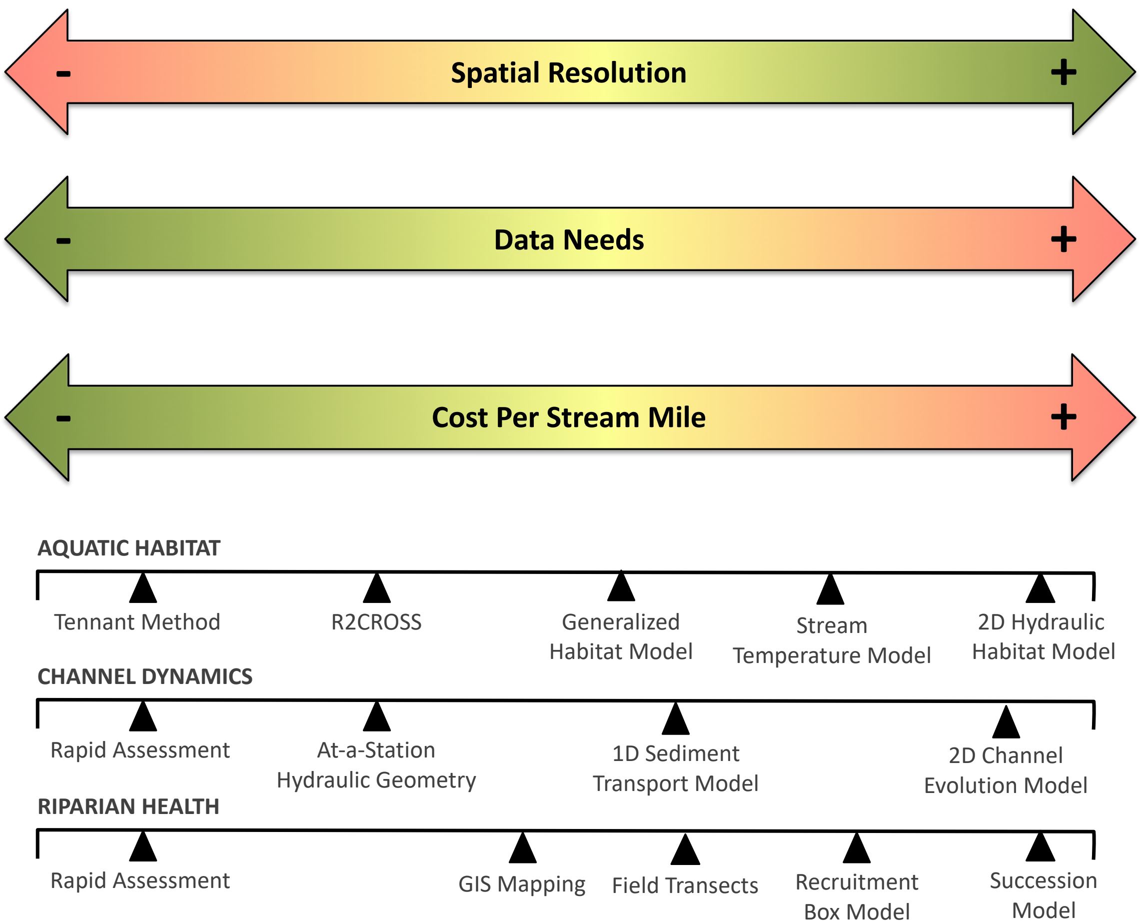


FIGURE 6. VARIOUS METHODOLOGIES USED TO CHARACTERIZE DIFFERENT ASPECTS OF ECOLOGICAL STRUCTURE OR FUNCTION. SELECTION OF ANY ONE METHOD OFTEN REFLECTS CONSTRAINS IMPOSED BY BUDGET, CAPACITY, OR GEOGRAPHIC SCOPE.

Flow Regime

Broad patterns of precipitation and topography determine a river's natural flow regime, but flow regime may be altered by human activities such as water management (withdrawals, augmentation, diversions), dams and reservoirs, or widespread land use changes in the watershed. Alterations to natural patterns of flow, including the frequency and timing of floods and droughts, impact fish, aquatic insects, and other biota with life history strategies tied to predictable flow patterns. Changes to peak flows may impact channel stability, riparian vegetation, and floodplain functions. Impacts to base flows may alter water quality and the availability of aquatic habitat. Fluvial ecologists generally treat flow regime as the "master variable" exerting the largest influence on riverine ecosystem form and function (Poff et al., 2010).

The flow regime is represented by hydrographs and flow duration curves that characterize the timing, magnitude and frequency of flow conditions, and alterations can be characterized by statistical range of variability analysis (Richter, et al., 1996) or visual comparison of hydrographs and flow duration curves. The Hydrology **data dashboard** includes estimates for many of these statistics at locations across the Colorado River basin using the Colorado Decision Support System StateMod simulation model.

Sediment Regime

Streams and rivers tend to be naturally adapted to the characteristic flow and sediment regime of their watersheds. The sediment regime reflects the amount and timing of sediment supplied to a reach from all sources. The sources of sediment to the reach are land erosion in the contributing watershed and channel erosion on reaches upstream. The production and transport of sediment within a stream network is a crucial determinant of channel form and dynamics.

Functional characterizations of sediment regime consider the amount and timing of sediment production, as well as patterns of sediment transport along the stream channel. Evaluation criteria may be based on the number and size of barriers to sediment transport and on the proportion of the watershed from which sediment transport is blocked or elevated above reference conditions. Deforestation, fires or dam construction can all alter sediment regime characteristics. Like changes to flow regime, an altered sediment regime may cause a cascade of impacts to stream form and function. The GIS maps and **data dashboards** developed through this project can be useful for identifying locations where reservoirs and other infrastructure may impede sediment transport.

Water Quality

Water quality is determined by a combination of upstream land and water uses, natural geological weathering, and biogeochemical processing. Water quality parameters are typically the most quantified and monitored aspects of stream health. The existence of regulatory standards and Water Quality Control Division assessment methodologies for a variety of water uses (e.g. aquatic life support, drinking water supply, direct contact recreation, etc.) make assessments of existing or historical water quality conditions relevant to consumptive and non-consumptive water uses fairly straightforward. Summaries of recent water quality data for the Colorado River basin are available on the Water Quality and Water Quality Regulation **data dashboards**.

Network Connectivity

Network connectivity considers longitudinal pathways for the movement of biological organisms and other organic material through stream and riparian corridors. These passageways for plant and animal migration are primary determinants of species distribution, habitat use, and energy flow. Barriers like dams, weirs, culverts and dry-up points may impede migration of fish and other aquatic species. Detritus flow may be interrupted by the same sorts of barriers. Patterns of woody material flow in stream networks are often interrupted by bridges, culverts, and other stream crossings and by the physical removal of materials in floodway maintenance and debris removal efforts.

Invasive riparian vegetation and alterations to floodplain hydrology may limit ecological continuity through riparian corridors, which are important migration pathways for both aquatic and terrestrial organisms. Barriers that isolate streams from adjacent upland habitat limit the transfer of organisms and energy between terrestrial and aquatic systems. The **studies library**, maps displaying locations of impoundments and other diversion infrastructure, and the Hydrology **data dashboard** can help with initial identification of physical or hydrological disruptions to network connectivity.

Floodplain Hydrology

Assessments of floodplain hydrology consider the degree to which water accesses and hydrates the land adjacent to the stream. The timing, extent, duration, and depth of floodplain inundation are largely responsible for the structure and complexity of riparian habitats. The seed dispersal, deposition, and scouring of soil surfaces that occurs during flood events controls the distribution of riparian forest species. Overbank flows recharge alluvial aquifers and raise the local water table, creating favorable conditions for hydric riparian vegetation. Seepage from charged alluvial aquifers back to the river later in the season is important for maintaining base flows, and moderating water temperatures. The extent of effective floodplain may be impacted by hydrologic modifications, channel alterations (e.g. enlargement, entrenchment, channelization), or land uses in the floodplain area (e.g. levees, drainage ditches, development, floodplain fill) that impede overbank flow frequency and lateral distribution. The Hydrology and Hydrologic Alteration **data dashboards** can indicate some locations where floodplain hydrology may be compromised.

Riparian Vegetation

Riparian areas contain complex assemblages of plant species that interact directly with the river. Root systems increase bank stability and the vegetative overstory provides habitat , leaf litter and shading for aquatic species. Riparian forests supply the stream with woody material as well as leaf litter. Large, woody material provides a structural component of the stream and floodplain, and in many stream types it is a critical factor in channel hydraulics, sediment distribution, and habitat complexity. Leaf litter is the primary source of carbon and energy that form the base of stream ecosystem food webs.

Important considerations for evaluating riparian forest health include the extent of riparian vegetation, cover, functional guilds, species diversity, the distribution and age class structure (or patchiness) of plant assemblages, and the presence of invasive species. Riparian vegetation may be impaired by direct impacts to vegetation associated with riparian area land use and development, or indirectly by impacts to flow and sediment regime, ecological connectivity, and/or floodplain hydrology. The **studies library** includes mapping resources and studies related to riparian vegetation in the Colorado River Basin.

Fluvial Geomorphology

Fluvial geomorphology encompasses the physical processes that interact to control channel form and evolution. The form and evolution of stream channels reflects interactions between the watershed's physical attributes (e.g. surficial geology, topography, hydrology), channel hydraulics, and local hillslope and floodplain use practices (e.g. transportation corridor alignment, grazing practices). Biological drivers such as the type and extent of riparian vegetation, inputs of large woody debris, beaver activity, and aquatic vegetation may also have a profound effect on rates and patterns of local sediment transport.

Stream corridors exhibiting geomorphic patterns not characteristic for local valley form, hydrology, and sediment regime may display elevated sensitivity to disturbance, rapid changes in channel form, or a reduction in complexity. Human management activities that modify the hydrological regime, alter patterns of hillslope erosion, adjust the structure of the channel bed, or modify riparian vegetation may yield fundamental shifts in the geometry and behavior of the stream. Impacts to fluvial geomorphology thus arise from construction of roads and levees on floodplains, extirpation of beavers, armoring stream banks, and constructing dams. The **studies library** includes information related to fluvial geomorphology for some locations in the Colorado River Basin.

Aquatic Habitat Complexity

The physical structure of a stream is the result of complex interactions between flow and sediment regime, ecological connectivity, floodplain hydrology, and riparian vegetation. Processes of erosion, scour, and deposition control stream bed, bank, and floodplain morphology, and the distribution of substrate types in the stream.

Assessments of aquatic habitat complexity consider water depth and velocity distributions, the variety of streambed and bank features, and distributions and types of substrate material. Macroinvertebrates or fish larvae respond to the availability of interstitial space in river bed substrate, degree of embeddedness, armoring, proportion of fine sediment, aquatic vegetation or algae cover, and patches of organic materials or detritus, such as leaf packs and wood. Physical habitat for fish and larger animals is controlled by the distribution and diversity of water depth and velocity combinations including relative abundance of pools, runs, riffles, and glides and variability within each one of these classes. Physical cover like overhanging banks and vegetation, and structure provided by wood, rock, vegetation, and debris dams and jams are also important physical habitat components. Many aquatic species rely on specific and relatively narrow ranges of water depth, velocity, and substrate types for feeding, resting, and spawning, or to complete different life stages. Aquatic habitat complexity is, therefore, a primary determinant of aquatic species diversity and trophic structure (food chain length). Activities that physically alter the structure of the stream bed and banks, disrupt the flow and sediment regime, alter the floodplain hydrology or riparian vegetation, affect fluvial geomorphology, or reduce large woody material may impair aquatic habitat complexity.

Aquatic Biota

The biotic makeup of a stream is impacted by all other stream health factors. Because aquatic biota depends on all other aspects of stream function, this apex variable is a prime indicator of overall stream health. Activities that impair processes at the watershed, reach, or channel scales often have effects on biotic structure. Interactions between hydrologic, geomorphic, and physicochemical factors create the physical template upon which biotic assemblages exist. Aquatic biota is further shaped by competition, predation, parasitism, and disease. Introductions of invasive species may lead to displacement or extirpation of native species.

Assessments of aquatic biota consider the total biomass and species diversity of microbes, macrophytes, macroinvertebrates, fish, amphibians, and all other plants and animals that form part of the aquatic biological community for all or part of their life histories. Ecosystems supporting complex trophic structure and long food chains are more resilient to human disturbance and changing external forcing variables like climate. The **studies library** includes several documents that discuss the health of aquatic biota in different locations around the Colorado Basin.

TABLE 2. EXAMPLE METHODOLOGIES FOR ASSESSING ECOSYSTEM STRUCTURE AND PROCESSES.

Measure of Ecological Integrity	Potential Indicators	Relevant Data Sources	Assessment Tools, Techniques, & Methods
Flow Regime	Peak flow, low flow, rate of change, low flow pulse, zero flow days	USGS gauges, CDSS models, Hydrobase, USGS StreamStats, CBRT data dashboards	Indicators of Hydrological Alteration
Sediment Regime	Hillslope erosion, watershed yield, bedload, suspended load	National Hydrography Dataset, Soil Survey Geographic Database	Network connectivity analysis, WEPP model, rapid-assessment, effective discharge analysis
Water Quality	Metals, nutrients, water temperature, pH, dissolved oxygen, inorganic compounds	EPA STORET, USGS NWIS, Colorado Data Sharing Network, CBRT data dashboards	Colorado Water Quality Control Division regulatory assessment methodologies
Corridor Connectivity	Continuity, barriers to migration or materials flow	National Hydrography Dataset, Colorado Source Water Route Framework, CDWR water rights structures mapping	Barrier identification, contiguous stream mile mapping, dendritic connectivity index analysis
Floodplain Hydrology	2-year, 5-year, 10-year flood inundation extent	FEMA flood hazard mapping, USGS gauges, CDSS models, National Elevation Dataset, Colorado LiDAR imagery repository	1D/2D hydraulic models (e.g. HEC-RAS)
Riparian Vegetation	Riparian forest extent, rare and significant species, habitat patchiness, species distribution and age class structures	CPW riparian mapping, CNHP vegetation mapping, National Wetlands Inventory, National Land Cover Database	Field mapping/transects, rapid-assessment, recruitment box model, vegetation succession model
Fluvial Geomorphology	Lateral migration rate, sinuosity, width-depth ratio	USGS aerial imagery, FEMA flood hazard models, USGS gauges, engineering studies	Effective discharge analysis, 1D/2D channel migration and sediment transport models
Hydraulic Structure	Depth, velocity, bathymetric/hydraulic variability, large woody debris	USGS gauges, CDSS models, National Elevation Dataset, Colorado LiDAR imagery repository	Rapid assessment, desktop habitat mapping, 1D/2D hydraulic models (e.g. HEC-RAS, River2D, FASTMECH)
Aquatic Biota	Native fish species ranges, fish species distribution and age class structures, amphibian presence absence, macroinvetebrate community health indices	USFS/BLM/CPW aquatic species survey results, macroinvetebrate MMI Scores published by state and federal agencies	Comparison of existing species ranges with native ranges, application of Water Quality Control Division assessment methodologies to MMI scores

EVALUATE CAPACITY FOR RIVERS TO DELIVER GOODS AND SERVICES TO COMMUNITIES

Rivers and streams freely provide a number of economic and social benefits across the Colorado River basin. These include clean water for municipal and agricultural use, flood protection, and landscape aesthetics—values to society that can be measured in terms of human health, direct economic valuation, or quality of life (Maes et al., 2016). Conversation with Colorado River basin stakeholders and reflections on recent integrated water management planning efforts by practitioners indicated that consideration of these services alongside assessments of ecological condition can help make the premise for IWMPs more worthwhile for many participants. Furthermore, reflection on the relationships between ecological conditions and the balance between supply and demand for the services rivers provide to communities can elucidate important opportunities and constraints for resource management actions that benefit river ecology.

Recent thinking in natural resource management suggests classifying services rivers provide to communities as provisioning services, regulating and maintenance services, and cultural services (Millennium Assessment Board, 2005). Provisioning services include energy or material outputs from the river system. They include water supply for agricultural, municipal, hydropower, and industrial uses. Regulating and maintenance services include the downstream flood abatement and groundwater recharge provided by unconfined, undeveloped floodplains; erosion control and soil loss avoidance derived from intact and healthy riparian zones; and the self-purification and nutrient-assimilation processes occurring in the water column and floodplain. Cultural services include the sense of identity provided to communities from streams and rivers, the psychological and spiritual value individuals derive from nature, and the numerous socio-economic benefits that arise from recreational boating, angling, and other social uses of river ecosystems.

PROVISIONING GOODS AND SERVICES

- Agricultural Production
- Drinking Water Supply
- Industrial Processing
- Hydropower Production

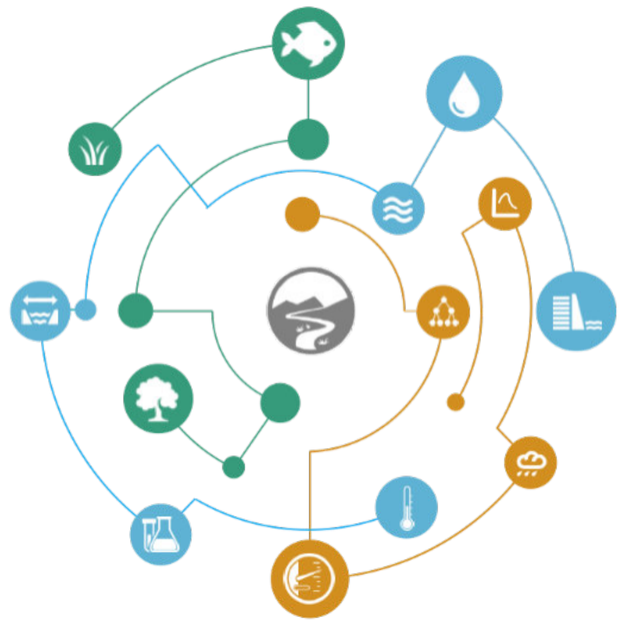
REGULATING AND MAINTENANCE GOODS AND SERVICES

- Flood Regulation
- Groundwater Recharge
- Erosion Control
- Pest Regulation
- Regulatory Compliance

CULTURAL GOODS AND SERVICES

- Aesthetics and Intrinsic Values
- Symbolic & Emblematic Species
- Boating Recreation
- Angling Recreation

The assessment framework recommends considering the following specific services that rivers provide: agricultural production, drinking water supply, industrial processing, hydropower production, flood regulation, groundwater recharge, erosion control, pest regulation, regulatory compliance, aesthetics and intrinsic values, symbolic and emblematic species, boating recreation, and angling recreation.



When delivery of these services is acutely constrained, local economies, livelihoods, and quality-of-life can suffer. These impacts may be severe enough to motivate assessment of alternative resource management strategies. Specific river services may be strongly connected to ecological conditions. Therefore, changes that enhance the delivery of one service may positively or negatively impact the delivery of another or may fundamentally change some aspect of ecological condition. The inverse is also true. Changes that benefit riverine physical processes or ecology may positively or negatively impact a river's capacity to deliver important services to the community. These considerations form the basis for cost-benefit analyses and alternative prioritization activities in subsequent planning steps.

Assessment of a river's capacity to deliver services that matter to local communities can be made using qualitative and/or social-science methodologies applied through targeted stakeholder engagement activities. Provisioning services, like supplying irrigation water, are fairly straightforward to assess quantitatively. It is often more difficult to quantify other services rivers provide to communities, given their nature as non-market, common public commodities. Fishing opportunities, bald eagle nests, and stunning viewscapes provide intangible benefits that do not easily fit within the economic valuation frameworks that might be used to drive resource management decisions in other settings. More qualitative social science methodologies may best capture how well a river is delivering these kinds of services.

Regardless of the selected approaches, characterization of the services rivers provide to communities should focus on the balance between demand for and delivery of those goods and services to local communities. This assessment framework does not prescribe use of specific methodologies but does recommend that any IWMP effort include an evaluation of each of the goods and service categories listed above. A definition and brief discussion of each is provided in the subsections below.

Agricultural Production

Surface water diversions from streams and rivers throughout the Colorado River basin support irrigated commodity crop production and hay-pasture for livestock. These uses comprise the predominant annual West Slope water use by total volume. Irrigated water use supports other stream functions and water-related values, including near-stream groundwater recharge, land conservation and maintenance of open space, and maintenance of in-basin water rights.

Changes to seasonal streamflow patterns or exercise of downstream senior water rights might limit the ability for local users to access water for agricultural production. The ability to effectively irrigate may also be restricted by the condition of diversion, conveyance and application infrastructure. In many cases, irrigation infrastructure issues can both limit a producer's ability to effectively irrigate, particularly during dry conditions, and impact stream ecology (North Fork Water Conservancy District, 2017).).

A coarse analysis of when and where agricultural water shortages may exist is provided in the Water Use **data dashboard**. Targeted identification of irrigation infrastructure needs can be accomplished through engineering assessments or interviews with irrigators and water commissioners. It is essential that any such assessment be undertaken only with the full cooperation of irrigators and a clear notion of potential benefits for them to take part. Local Conservation Districts or other agricultural organizations can be good partners or lead organizations in assessing agricultural needs and communicating with irrigators. The Natural Resource Conservation Service Field Office Technical Guide is a rich source of data on agricultural and natural resource conditions (https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/fotg/) that may also aid in these investigations.

Drinking Water Supply

River systems provide drinking water supply for most, if not all, of the municipalities in Colorado River basin. Healthy systems that are able to fulfill their other ecosystem services such as pollutant assimilation and self-purification are far more likely to effectively support drinking supply by contributing to reduced treatment costs for pollutants including sediment, pathogens, metals, and nutrients. Changes to seasonal streamflow patterns or the exercise of downstream senior water rights might limit the ability for local communities to utilize surface water for drinking water supply. Water quality conditions may similarly limit municipal use opportunities or increase treatment costs. Looking ahead, population growth and hydrologic changes brought about by climate change could prompt concerns about the security and resilience of a community's drinking water supply. A coarse analysis of municipal water shortages and undesirable water quality conditions for drinking water supply are provided in the Water Use and Water Quality **data dashboards**.

Industrial Processing

Although not perceived as heavily industrialized, the upper Colorado River basin does see water use for industrial production. These uses support coal production and cleaning, thermoelectric power generation, and oil and gas extraction. These uses are an important contributor to the vitality of some resource extraction-based economies in the basin. Limitations on industrial use of water arise from upstream water uses that limit water availability or exercise of downstream senior water rights that restricts the ability for local users to divert surface water or pump groundwater. A coarse analysis of when and where industrial water shortages may exist is provided in the Water Use **data dashboard**.

Hydropower Production

Limited hydropower production exists in the Colorado River basin. While these uses are not widespread, they represent an important component of the water rights administration regime and play a fundamental role in shepherding water through stream networks—water that contributes to ecological integrity and recreational use opportunities on stream segments upstream and downstream to the point of use, as well as consumptive uses downstream with junior water rights. Hydropower is an important component of renewable energy portfolios for local utilities and cooperatives. It is also the primary means by which the capital costs for several large Bureau of Reclamation projects in the upper Colorado River basin are recuperated. The water supply necessary to support hydropower production may be limited by native hydrology or the upstream exercise of water rights and reservoir operations. The condition of aging hydropower generation infrastructure may similarly limit this water use. A coarse analysis of when and where water shortages for hydropower may exist is provided in the Water Use **data dashboard**.

Flood Regulation

Functional floodplain morphology and riparian vegetation play key roles in moderating the downstream effects of flood flows—flows carrying potentially destructive energy to downstream communities in low-lying areas. Stream reaches with large unconfined floodplains exhibiting healthy riparian forests serve as temporary natural reservoirs. These floodplains moderate extreme flood events by allowing high flows to spread across the landscape where they are slowed by vegetation, retained temporarily as surface storage and released over longer time scales through groundwater infiltration. These mechanisms moderate downstream peak discharges. Floodplain clearing or filling, river entrenchment and straightening, bank armoring, or other alterations all reduce a river's natural flood regulation capacity.

Steep headwaters streams or geomorphologically confined reaches like canyons may have little or no natural capacity for flood regulation. Therefore, demand and capacity for this flood regulation is highly-relative to the presence of an unconfined floodplain. Intact floodplains provide flood regulation benefits directly to downstream reaches, and indirectly to system-wide reaches. However, the need to protect human infrastructure and other assets in near-stream areas may compete directly with management of floodplains for downstream flood regulation.

Groundwater Recharge

Water supplied to alluvial aquifers from streams during flood events, from irrigated agriculture, or from direct infiltration through the streambed is a vital component to annual water budgets in many areas. Groundwater recharge controls shallow aquifer levels that support agricultural or municipal water well production, revitalizes wetlands, supports soil fertility, and may supply late-season baseflows to some streams and rivers. Groundwater recharge to alluvial aquifers may be limited by confinement of river with dikes or other flood control infrastructure, bisection of alluvial floodplains by transportation infrastructure, reduction in flood flow magnitude and recurrence interval due to dam operation, or alteration of irrigation application practices. Examples of how to assess the contributions of agriculture to groundwater recharge and late season streamflows can be found in augmentation plans and water court cases addressing return flow issues. The Hydrologic Alteration **data dashboard** and the **studies library** may be helpful in identifying areas were altered flow regimes limit groundwater recharge on floodplains.

Erosion Control

Intact and robust riparian vegetation communities resist erosive bank shear stresses, moderating rates of lateral channel movement or reducing the probability of occurrence for large avulsions in lowland gravel bedded streams. Riparian areas along upland stream reaches play an important role in moderating elevated loads of sediment sourced to the stream from hillslopes exposed to forest fire, logging, or urban development. Unmitigated increases in sediment loads (or decreases due to the presence of water impoundments) may cause downstream channel incision or aggradation and subsequent changes in channel geometry or form that local communities may find undesirable. Engineering approaches to dealing with "excessive" erosion along river channels may include streambank or bed armoring. Such approaches may be appropriate and effective tools for infrastructure protection in some areas but may exacerbate undesirable patterns of upstream/downstream channel erosion in other areas.

Pest Regulation

The presence of invasive aquatic and riparian species like Northern Pike, Smallmouth Bass or Tamarisk in Colorado streams and rivers continues to present management challenges to landowners, conservation groups, resource agencies, and other stakeholders. Invasive riparian species reduce biodiversity, change the aesthetic qualities of waterways, and might impact channel dynamics by altering local sediment transport dynamics. Aquatic fish species classified as pests regularly outcompete native species and sport fish alike, limiting biodiversity and changing recreational angling opportunities for local residents and visitors. Hydrological alteration or geomorphological modification due to changes in the sediment regime or physical alteration of floodplains can produce conditions favorable to invasive pest species. The Hydrologic Alteration **data dashboard** and the **studies library** may be helpful in identifying areas were invasive species are a problematic regulatory issue or limit delivery of some important service to local communities.

Regulatory Compliance

The Colorado Department of Health and Environment Water Quality Control Division implements the Clean Water Act by regulating pollutant effluent primarily generated by industry or municipal wastewater treatment. Regulation takes the form of surface water standards for water quality and a permitting process that places limitations on pollutant dischargers. The purpose of regulation is to ensure that surface waters continue to support a diversity of uses.

Rivers and streams serve as a natural transport, distribution, and attenuation system for natural and human-sourced additions to the water column. These additions include metals from mines; nutrients from agriculture and wastewater treatment; and other constituents from residential, commercial, or industrial land uses. Where water quality conditions are degraded, the ability for local communities to use a stream as a source for drinking water or as a diluent for effluent discharges may be reduced. Furthermore, non-compliance with water quality regulations may lead to costly capital expenditures on wastewater treatment plant upgrades. Low flows can affect regulatory compliance by reducing the ability of a stream to dilute pollutants in discharges, which in turn can affect permitted discharge limits. The Water Quality Regulation **data dashboard** can aid in identifying reaches where a stream's ability to assimilate pollutants is overwhelmed.

Aesthetics and Intrinsic Value

Riverine ecosystems provide aesthetic value as quintessential elements of western viewscapes. Aesthetic enjoyment and appreciation also drives high rates of usage in riverside parks and trails by residents and visitors in communities throughout the basin. Riparian areas provide a masking effect for built-environments, buffering noise and visual impacts from developed areas—helping maintain a culturally-expected 'look and feel' of western Colorado communities. Communities participating in the recreational tourism, service, and resort economies achieve high productivity and economic output by attracting residents or visitors who place high personal value on aesthetics of mountain landscapes. Many residents and stakeholders additionally believe that riverine plants, animals, and physical processes that support them have intrinsic value independent of their instrumental or economic worth to human populations. This belief system provides an argument for the conservation, maintenance, and support of riverine ecosystems for their own sake, regardless of human valuation: a 'working' and 'healthy' river system is an end in and of itself, rather than a means to additional human ends.

Symbolic & Emblematic Species

Clean streams and the attendant healthy riparian forests and wetlands support an outsized biodiversity compared to other components of the arid western landscape. Numerous symbolic or emblematic species utilize river corridors for breeding, forage, and migration. Iconic species in the Colorado River basin include, but are not limited to, eagles, osprey, cutthroat trout and river otters. The presence of these species is largely related to aquatic and riparian habitat conditions, which in turn are driven by local and regional patterns of land and water use.

Boating Recreation

Boating recreation includes activities like inner-tubing, standup-paddle boarding, rafting and whitewater kayaking. Some types of boating recreation (e.g. float fishing) are also tied closely with recreational angling. The rivers in the Colorado River basin include many notable whitewater runs and several segments draw millions of dollars into tourism economies. Like instream flows for ecosystem needs, recreational flows are a non-consumptive water use that is increasingly incorporated in water policy frameworks. Flows that support recreational boating have strong seasonal and geographic components. Quantification typically occurs via social research methods such as user-preference surveys. Limitations on recreational boating use may arise from upstream administration of water rights or reservoir operations that change the timing and magnitude of flows in a given stream reach. Limitations may also be imposed by lack of river access points or due to the presence of instream structures that impede boat passage.

Angling Recreation

Angling recreation includes float fishing and wade fishing. Western Colorado features vibrant streams known for robust trout fishing opportunities, as well as other angling options. In resort-based communities, angler outfitting and retail services may supply a significant revenue base. Quantification of constraints on angling recreation may involve user-preference surveys that relate flow levels to angling success or user enjoyment. Because the presence of desirable fish species is directly related to the angling experience, reductions in aquatic habitat quality or availability imposed by upstream water depletions may impair angling recreation. Lack of river access points may similarly limit this type of use.

TABLE 3. EXAMPLE METHODOLOGIES FOR ASSESSING BENEFITS COMMUNITIES RECEIVE FROM STREAMS AND RIVERS.

Goods and Services	Possible Indicators	Relevant Data Sources	Assessment Tools, Techniques, & Methods
Agricultural Production	Water use shortage/surplus. Ease of water delivery.	CDSS Hydrobase diversion records; Water conservation district records; StateCU; StateMod, USGS NWIS; CBRT data dashboards; engineering studies	Consumptive water use analyses; irrigated acreage analyses; interviews with producers
Drinking Water Supply	Water use shortage/surplus. Attainment of drinking water standards	CDSS Hydrobase; public provider permit records; surface water monitoring data: USGS NWIS, EPA STORET, CDPHE, River Watch; CBRT data dashboards	Drinking water use class standards attainment; supply/demand analyses; SWPP; current/historic use quantification; climate change and watershed event risk assessments
Industrial Production	Water use shortage/surplus	CDSS Hydrobase; USGS NWIS; CBRT data dashboards	Water demand/use analysis

Hydropower Production	Water use shortage/surplus. Plant outages.	CDSS Hydrobase; CPDES permits; surface water monitoring data: NWIS, STORET, CDPHE, River Watch; CBRT data dashboards	Water demand/use analysis
Flood Regulation	Unconfined floodplain extent	FEMA datasets, NED or local elevation data, USGS gauges	HEC-RAS or other models; overbanking return flow analysis; narrative historic records and photos
Groundwater Recharge	Alluvial aquifer water table heights; riparian and floodplain wetlands presence/absence/acreage; flood overbanking frequency.	Well logs, CDWR groundwater data; USGS gauge records; Hydrobase	Seasonal/annual groundwater level monitoring; floodplain/soils mapping; overbanking frequency analysis; inundation modeling; MODFLOW modeling
Erosion Control	Riparian vegetation health; channel migration rates; channel downcutting/incision rates.	Reach assessment reports from BLM, NRCS, USFS. Local engineering studies.	Rapid assessments including: COSHAF, BLM PFC, NRCS, USFS; bank shear modeling; historical channel alignment/migration analysis; turbidity/suspended sediment and bed load budgets.
Pest Regulation	Presence/absence/extent of invasive species.	CPW Riparian mapping; CNHP vegetation mapping; NLCD; LandFire; local land owners; County or municipal government (noxious weed authority); local conservation districts	Time series species extent comparisons; vegetation succession modeling; bank scour analysis.
Regulatory Compliance	Attainment of water quality standards. Effluent discharge permit violations.	NWIS; STORET; CDSN; CDPHE; CPDES permits; USGS studies;	WQCD standards assessment protocols; mixing zone analysis; macroinvertebrate assemblage analyses; time series and trends analyses; EPA BASINS modelling toolboxes
Aesthetics and Intrinsic Values	Presence of river-related attributes in community identity; Conservation easements; Instream flow rights; Aesthetic values present in planning or zoning codes.	USFS; BLM; CPW; Town governments; Tourism advertising or businesses	Social research methods: personal interviews/surveys; visitor use surveys;
Symbolic or Emblematic Species	Rare or threatened species counts; number/extent of special use/high sensitivity habitats; acreages of intact habitat for connectivity or migration	CNHP; CPW; USFS; USFWS; TNC; TU; WWF; Biological surveys	Corridor mapping; time series habitat extent comparisons
Boating Recreation	Count and condition of river access points, count of impassable barriers, number of 'boatable' days	American Whitewater; CPW; USFS; BLM; CROA; local outfitters and retail	Flow preference surveys; boatable days analysis
Angling Recreation	Count and condition of river access points, count of impassable barriers, 'fishable' days analysis	CPW; USFS; BLM; TU; local outfitters and retail services	Angler preference surveys; Creel surveys; user days reviews; flow preference surveys; fishing 'effort' analyses

By considering each of the factors above, the assessment framework seeks to support water management decision-making that supports non-consumptive water uses while, simultaneously, alleviating constraints on the delivery of other important services rivers provide to local communities. This integrated approach helps stakeholders simultaneously consider undesirable ecological conditions and the value perceptions that may constrain or support actions to address those conditions. A straightforward scoring system makes assessment results simpler and easier for non-technical audiences to grasp and act upon (Johnson et al., 2009; Burkhard et al., 2012). It is recommended that IWMP efforts employ two sets of scoring criteria: one for ecological assessment results (Table 5), the other for characterizing the human benefits received from streams and rivers (Table 6). Scores can be expressed numerically or by using the more intuitive academic grading scale (A-F). The methods used to translate statistical or numerical assessment results and more subjective measures into individual scores is largely left to stakeholders and practitioners, providing flexibility in how the assessment framework is applied. The River Health Assessment Framework (City of Fort Collins, 2015 the FACStream manual (Beardsley et. al., 2015) and the FACWet manual (Johnson et al., 2009) may be instructive in this regard.

IMWP planning efforts should report assessment scores for each planning unit and for the entire set of ecological indices and measures of river services to communities using a standard format. The example worksheets attached in Appendix A may facilitate such structured reporting. Assessment results can be presented using maps and color-coded matrices (Figure 7). Results organized in either format are easy to interpret, and may be used to guide discussions about the relationships between ecosystem condition and the delivery of services to communities within a planning unit. This approach to visualizing results may also help users identify the relationships between conditions in a given planning unit and the driving factor(s) in upstream units. Recognition of relationships between conditions throughout the river continuum is fundamental to the success of integrated water management planning.

TABLE 5. RECOMMENDED SCORING SYSTEM FOR ASSESSMENTS OF ECOLOGICAL STRUCTURE AND PROCESSES.

Numeric Score	Academic Score	Description
5	A	Structure or process is in pristine or 'reference' condition
4	B	Mild or episodic alterations to structure or process are evident. Alterations do not significantly impact overall ecosystem condition.
3	C	Significant or chronic alteration to structure or process observed. Alterations contribute to degradation of overall ecosystem condition.
2	D	Alterations to structure or process are chronic and extreme. Significant intervention may be required to improve observed conditions and/or prevent further consequential impacts to overall ecosystem condition.
1	F	Profound or irreversible alterations to structure or process evident.
0	NA	Not applicable to the planning unit or not assessed.

TABLE 6. RECOMMENDED SCORING SYSTEM FOR ASSESSMENTS OF THE SERVICES STREAMS AND RIVERS PROVIDE TO COMMUNITIES.

Numeric Score	Academic Score	Description
5	A	Good or service is delivered at the desired rate or quantity at all times.
4	B	Good or service is delivered at the desired rate or quantity most of the time. Minor imbalances between the demand for and delivery of the good or service are evident.
3	C	Imbalances between the demand for and delivery of the good or service are chronic and are deemed moderately problematic by the local community.
2	D	Imbalances between the demand for and delivery of the good or service are chronic and are deemed severely problematic by the local community.
1	F	No delivery of the good or service at any time despite the existence of some demand for it.
0	NA	Not applicable to the planning unit or not assessed.

	Ecosystem Condition										Benefits to Local Communities															
SMiRF ID	**Ecological Integrity**	Flow Regime	Sediment Regime	Water Quality	Network Connectivity	Floodplain Hydrology	Riparian Vegetation	Stream Corridor Dynamics	Structural Complexity	Aquatic Biota	**Provisioning**	Agricultural Production	Drinking Water Supply	Industrial Processing	Hydropower Production	**Regulating and Maintenance**	Flood Regulation	Groundwater Recharge	Erosion Control	Pest Regulation	Regulatory Compliance	**Cultural**	Aesthetics and Intrinsic Values	Symbolic/Emblematic Species	Boating Recreation	Angling Recreation
1.1		1	2	1	0	0	2	3	2	1		1	4	0	1		1	2	3	2	1		1	1	1	2
1.2		2	3	2	2	3	3	4	1	1		2	2	3	2		2	3	4	1	1		2	2	2	4
1.3		4	3	3	3	1	3	5	3	2		3	3	1	4		4	3	5	3	2		4	2	4	5
2		4	2	4	2	3	2	2	2	2		4	5	3	4		4	2	2	2	2		4	2	4	5
3.1		4	4	4	3	5	4	3	5	3		4	1	5	3		4	4	3	5	3		3	2	3	1
3.2		1	1	1	0	0	1	1	2	1		1	4	0	1		1	1	1	2	1		1	0	1	2
4		3	2	3	4	2	2	1	5	4		3	4	2	3		3	2	1	5	4		3	2	3	2

FIGURE 7. EXAMPLE MATRIX FOR ORGANIZING AND PRESENTING ASSESSMENT RESULTS AROUND GEOGRAPHIC PLANNING UNITS, ECOSYSTEM CONDITION, AND RIVER SERVICES TO LOCAL COMMUNITIES.

Standardized templates and organizational approaches, like the matrix in Figure 7, are extremely useful for aggregating, visualizing, and presenting assessment results in stakeholder settings and in final reporting. It is critical that information generated by ecological assessments and evaluations of river services to communities is synthesized strategically so that planning outcomes can be more easily compared across the basin. Ultimately, the assessment framework discussed above reflects the CBRT's search for tools and techniques to aid in 1) contextualizing the need or opportunity for integrated water management planning in a sub-basin or watershed, 2) structuring and organizing investigations to reflect environmental conditions, municipal/industrial use needs, and agricultural use needs, and 3) reporting results back to the CBRT for synthesis and comparison.

At whichever stage in the planning process the matrix is used, it is critical that practitioners are transparent about how grades for each variable were assigned. The judgements behind grades for the portion of the matrix addressing services rivers provide to communities are inherently more subjective than the judgements on ecosystem condition, making transparency in presenting grades for this section particularly important. Different people, with different priorities and insights, may grade many of these variables differently for the same stream segments. Final reporting for each IWMP should include clear descriptions of the methodologies used to assess each variable and the criteria applied to assessment results for the purpose of scoring. In addition to clarifying what the grades mean, this will enhance the credibility of the report and provide the necessary context for comparing outcomes between multiple planning efforts.

Step 4: Select Objectives and Measurable Results

The information generated in the previous step will allow stakeholders to jointly consider the geographic locations of ecological conditions along a stream and how these needs intersect with local economies and human value systems. This phase of the planning effort requires stakeholders to identify specific planning objectives that respond to some issue revealed through assessments of existing conditions and characterization of the risk to those conditions imparted by some change to the system. The basic premise of integrated water management planning is the search for actions, projects, and processes that can support stream health, ideally in concert with irrigation needs and other river services valued by the community. An example ecological objective might involve decreasing the number of days where flows are above an identified low-flow threshold for trout habitat on some reach. Other ecological objectives might deal with peak flows critical to sediment transport and fish passage or overbanking conditions related to the health of riparian vegetation. Objectives build around services river provide to communities could include reducing agricultural irrigation shortages, improving water delivery infrastructure, or increasing the duration of seasonal flows optimal for recreational boating.

After building planning objectives around high-priority issues, stakeholders and practitioners must identify the metrics that will be used to predict the ability of some future alternative action to meet the stated objective. These 'measurable results' may include measures of hydrological regime behavior, measures of riparian forest extent or community composition, biomass of specific fish species, reduced "calls" on streams, the number of 'boatable days' available to users in drought years, etc. The most effective planning processes will characterize objectives in terms of the metrics used to assesses conditions and risk in earlier steps. The careful selection of measurable results will also be useful for structuring long-term monitoring efforts able to characterize the effectiveness of implemented actions.

Step 5: Identify Potential Alternative Actions

A set of candidate alternative actions identified by a stakeholder group to respond to a given planning objective should be based in general expectations regarding their relative feasibility and/or effectiveness (Figure 8). Typically, this means that the individuals and organizations represented by the stakeholder group believe they have or can seek out the technical resources, public support, funding etc. to implement a contemplated alternative. This does not mean that all alternatives must be immediately achievable; rather, that they should be grounded in reality and not contingent upon benevolent supporting actions of outside players. Alternative actions evaluated in recent integrated water management planning exercises across the Colorado River basin include, but are not limited to: physical modifications of stream beds, water leasing, water conveyance system efficiency upgrades, water application system efficiency upgrades, municipal water supply conservation programs, water diversion infrastructure modification, reservoir development or re-operation. Ideas for alternatives may be drawn from the stakeholders, from the Colorado Basin Implementation Plan, from special studies or engineering evaluations.

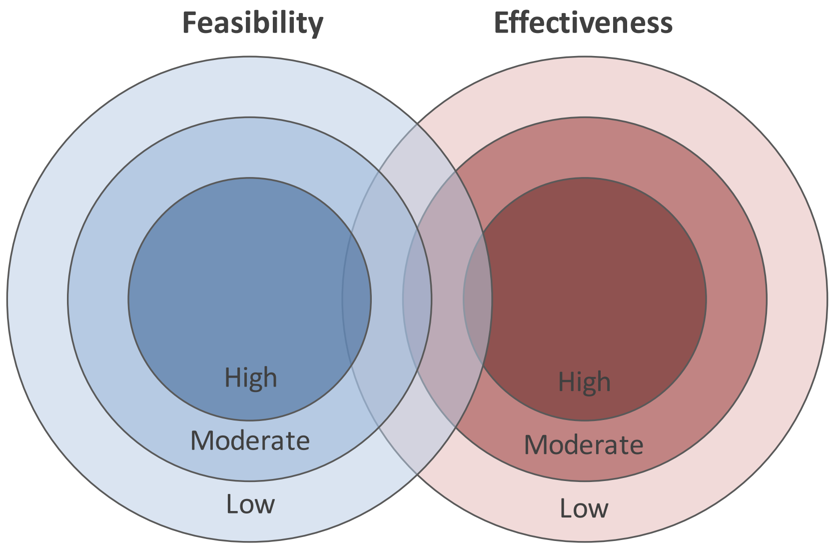


FIGURE 8. ALTERNATIVE IDENTIFICATION TASKS WILL GENERALLY PRODUCE A RANGE OF STRATEGIES WITH VARYING EXPECTATIONS FOR FEASIBILITY AND EFFECTIVENESS.

Step 6: Evaluate and Prioritize Actions

Stakeholders should reflect on information illustrating the different dimensions of effectiveness (at meeting project objectives) and feasibility (of implementation) of each alternative (Figure 9). The evaluation of alternatives should simultaneously consider the potential impact of each on ecological conditions and the ability of a stream or river to serve the needs and desires of local communities. While use of structured approaches are often advantageous, trade-offs for some intangible services that rivers provide to communities will likely be evaluated through simple dialog and subjective analyses with local stakeholders.

Qualitative and quantitative assessment or simulation approaches that speak directly to the measurable results identified Step 5 are best suited to characterization of an action's impact on ecological condition. An effective assessment of impacts to the services rivers provide to communities can help clarify the type and location of displaced costs of a given action. These displaced costs underlie a community's 'willingness to pay' for a given action. Hedonic pricing, direct market valuations, contingent valuation methods, land-use appraisals and many other methodologies might be used to conduct cost-benefit analyses for a range of contemplated alternative actions, projects, or processes.
Several other tangible factors should be assessed when considering the relative feasibility or effectiveness among a suite of alternatives. Considerations like legality, total capital cost, ongoing maintenance and operations costs, property ownership and accessibility, and institutional capacity are regularly incorporated into cost-benefit analyses.

This exercise should culminate in the assignment of relative priority levels for the alternative the projects, processes, and management actions considered by the planning effort. High-priority actions should be complemented by some variety of implementation plan development. The appropriate level of detail associated with any given implementation plans should be determined by stakeholders. Some plans will be conceptual in nature, while others may include some amount of engineering design. Regardless of the level of detail, implementation plans will generally include an identification of project champions, the availability of funding sources, the required technical or legal resources, and approximate implementation timelines.

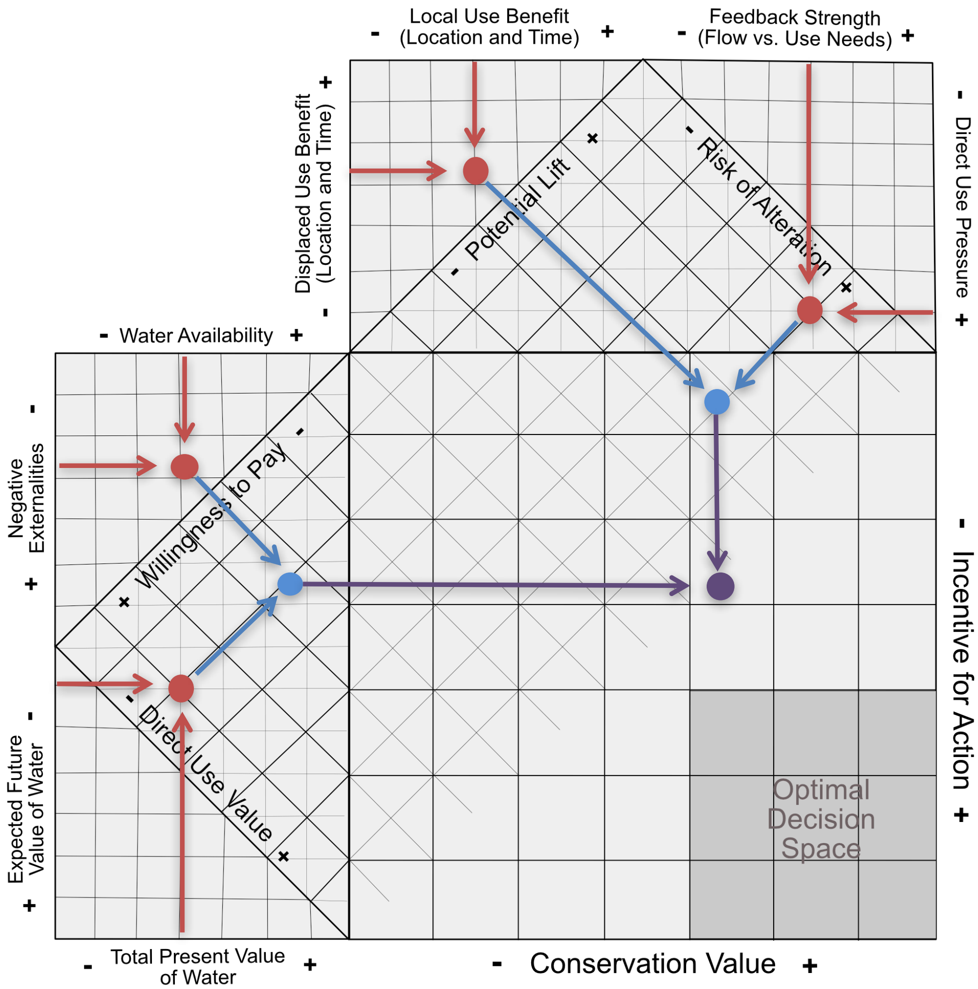


FIGURE 9. A HYPOTHETICAL EVALUATION SPACE FOR ASSESSING THE EFFECTIVENESS AND FEASIBILITY OF ONE TYPE OF ALTERNATIVE ACTION.

Step 6 is a logical breakpoint in the planning process and many integrated water management planning efforts will conclude here. Even in cases where a planning effort continues through the remaining steps, information generated in all previous steps should be collated in a manner that allows future stakeholders to reflect on the processes and methodologies employed to this point. Reporting documents should help future readers understand the planning context and how recommendations for certain actions came to be.

Step 7: Implement Priority Actions

Implementation of priority actions may require continued dialog among key stakeholders, especially for very large projects or ongoing management actions designed to respond to changing local conditions. The implementation plans developed in the previous step should be revisited, completed, or revised to provide a clearer understanding of the action's scope and scale. Project proponents will need to secure funding for capital investments or ongoing programs. There may be a need to build institutional capacity to sustain long-term efforts. Critically, on-going monitoring (see below) should be planned for and funded in this step.

Step 8: Monitor Implementation Outcomes

Repeated monitoring and characterization of changing ecological conditions or the services rivers provide to communities is needed to assess progress toward or away from the stated planning objectives. Monitoring results should be compared against planning objectives and measurable results. In the absence of such monitoring, it may be difficult or impossible to determine whether or not implemented action(s) had the intended effect. The frequency of repeated assessments should be determined by practitioners and stakeholders. It is critical that the planning for ongoing monitoring and the costs associated with it are embedded in final implementation plans for each implemented action.

Step 9: Manage Adaptively

Monitoring results may indicate changing conditions for ecology or the services rivers provide to communities. Those changes may be driven by uncontrollable externalities or may be the unintended outcome of an implemented action. Where the changes are undesirable, stakeholders may need to 1) consider new or different implementation approaches for existing high-priority actions, 2) revisit the evaluation and prioritization step while reflecting on new information, or 3) reinitiate the planning process in its entirety.

NEXT-STEPS

The authors of this document expect that future modifications to the outlined planning process and assessment framework will be necessary. The types of modifications needed will be elucidated by planning efforts that use this guidance on a test-case basis. We anticipate that the SMiRF may require future updates and modifications to maintain currency with the Source Water Route Framework and the USGS NHD Plus stream mapping layers. We also expect that further work may be required to simplify or standardize reporting structures for planning unit delineation and assessment methodologies. Updates may take the form of worksheet creation; development of a library of methodologies relevant to IWMP efforts; or development of websites, databases, and/or web-enabled data entry forms. It is also possible that some planning steps will be deemed unnecessary, or that the minimum set of indicators for characterizing ecological integrity or delivery of services to communities will require addition or modification. The emphasis and direction that future modifications to this document take should be based on the 'lessons-learned' through planning efforts that employ this guidance over the coming years. As more plans are completed, it will become increasingly clear where CBRT can take actions or request work to further lower barriers to entry and promote successful implementation of integrated water management planning. In the meantime, the Roundtable may contemplate the means by which it will encourage or require use of this guidance for planning across the Colorado River basin.

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APPENDIX A: EXAMPLE REPORTING WORKSHEETS

Study Unit Reporting Worksheet

Geographic Delineation

Planning Unit Name: ____________________

Planning Unit Description: ____________________

Downstream SMiRF ID: ____________________

Upstream SMiRF ID: ____________________

Ecological Indicator	Assessment Method ID	Score
Flow Regime		
Sediment Regime		
Water Quality		
Network Connectivity		
Floodplain Hydrology		
Riparian Vegetation		
Stream Corridor Dynamics		
Structural Complexity		
Aquatic Biota		

Ecosystem Good/Service	Assessment Method ID	Score
Flood Regulation		
Groundwater Recharge		
Erosion Control		
Pest Regulation		
Regulatory Compliance		
Agricultural Production		
Drinking Water Supply		
Industrial Processing		
Hydropower Production		
Aesthetics and Intrinsic Values		
Symbolic/Emblematic Species		
Boating Recreation		
Angling Recreation		

Method Description Worksheet

Assessment Method ID: ______________________________

Approximate Level of Effort (circle one):

Level 1 Level 2 Level 3

Method Description: ______________________________

____

____

____

____

____

Data Sources: ______________________________

____

____

____

QAQC Procedures: ______________________________

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____

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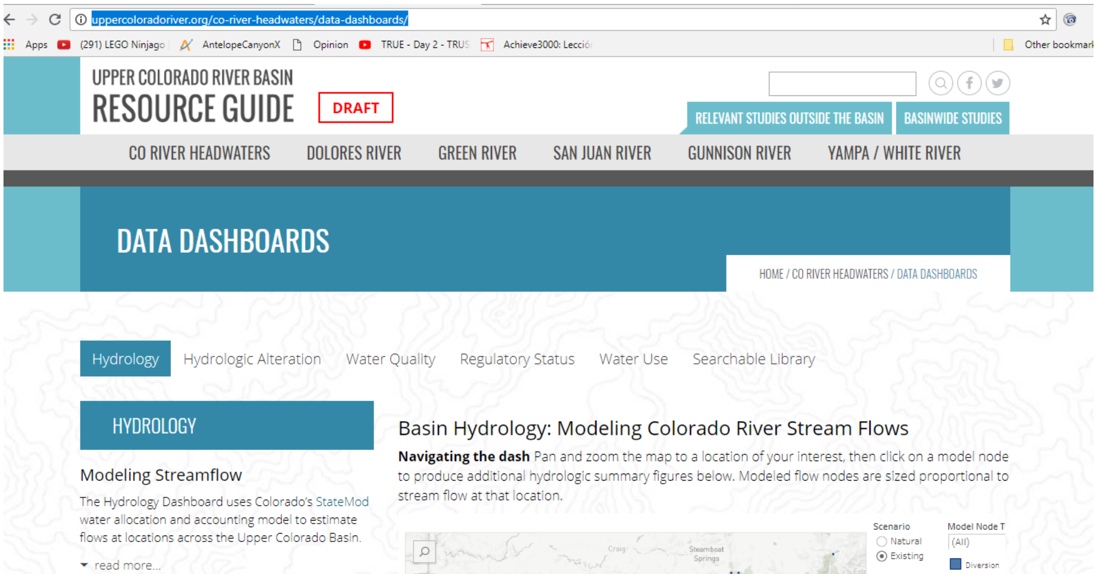
Scoring System	Desription of Scoring Criteria for Results Produced by Method
5 (A)	
4 (B)	
3 (C)	
2 (D)	
1 (F)	

APPENDIX B: SCREENSHOTS AND DESCRIPTIONS OF ON-LINE TOOLS

DATA DASHBOARDS AND STUDIES LIBRARY

The **data dashboards** and **studies library** referred to in this document can be accessed at http://uppercoloradoriver.org/co-river-headwaters/data-dashboards/. Each one is accompanied by documentation explaining underlying data sources and how to use them. **The spatial mapping layer** that delineates the major streams in the basin into stream mile units is in the **Searchable Library** dashboard.



INTERACTIVE MAPS

A set of **interactive maps** compiling data layers from numerous sources, including the Colorado Basin Implementation Plan, can be found on this portion of the site, at the link below the map depicted on the page: http://uppercoloradoriver.org/co-river-headwaters/colorado-headwaters-sub-regions/