River Health Assessment Framework

Cache la Poudre River

City of Fort Collins

2015

River Health Assessment Framework

<u>City of Fort Collins</u>
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August, 26 2015

Memorandum of Adoption

The River Health Assessment Framework was administratively adopted by:

______________________ 8/26/15

John Stokes, Natural Areas Director — Date

Carol A. Webb 8/26/15

Carol Webb, Water Resources and Treatment Operations Manager — Date

Executive Summary

The City of Fort Collins Natural Areas Department and Utilities Service Area have developed this **River Health Assessment Framework (RHAF)** to clearly define the City's **vision for a healthy and resilient** Poudre River. This vision includes aspirations for improving the Poudre River's health as well as sustaining current ecosystem function. The RHAF will help guide and inform the City's efforts to support watershed services and river management efforts. The scope of the RHAF encompasses the entire Poudre River as it affects the City, from its headwaters to Windsor, but with greater emphasis on the reach extending from the City's water supply intake in the lower Poudre Canyon to I-25.

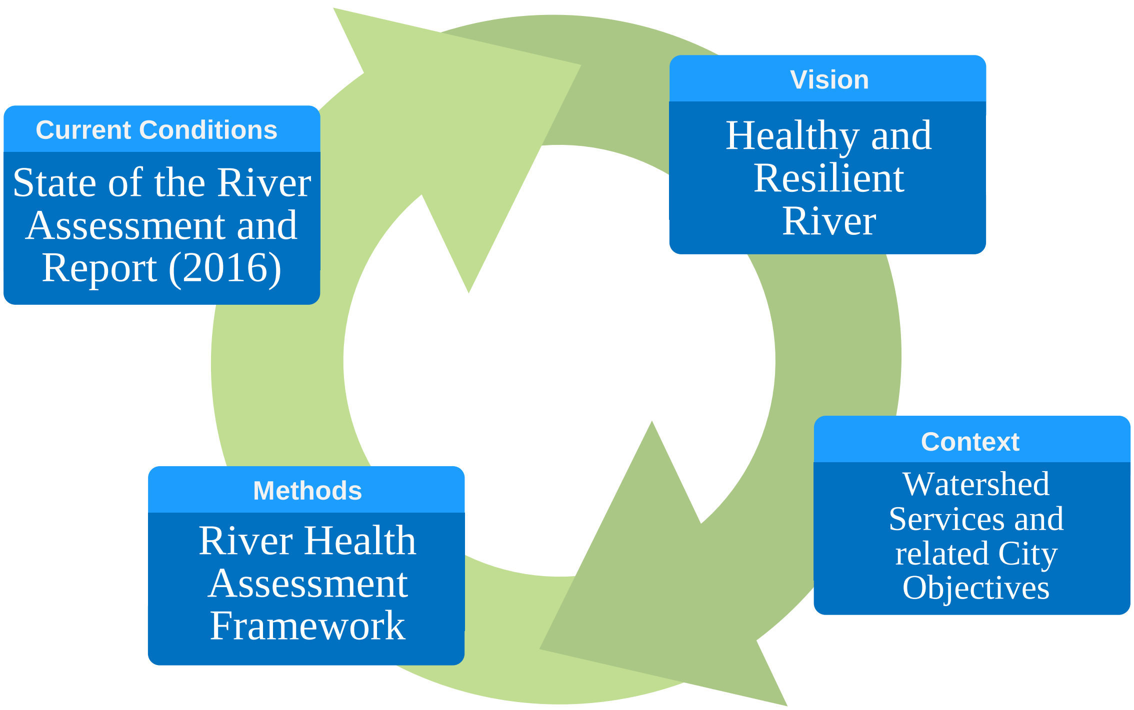
The RHAF is based on a recently developed river assessment methodology that has been refined and customized to fit the specific context of the Poudre River. This methodology is built around ten indicators that represent the essential physical, chemical, and biological elements of the river ecosystem. Each health indicator is described by several metrics that are measurable or observable aspects of the river ecosystem, such as water chemistry or the number of bird species detected.

The RHAF also supports the broad set of **watershed services** that a healthy River provides to the City of Fort Collins. These include a reliable water supply; floodplain and stormwater management; clean water; ecological health; and a source of recreation, health and wellness for the community. There are a diverse and complex set of City objectives related to these watershed services.

The RHAF describes a range of potential conditions for each indicator and then goes on to prescribe recommended ranges for each indicator. Generally, the embodiment of ideal health in ecosystems is native condition. The RHAF's recommended ranges acknowledge that, for many indicators, a return to native conditions is not feasible given the contemporary context and more than 150 years of changing conditions and anthropogenic impacts to the river. The recommended ranges attempt to identify the most beneficial yet feasible outcomes by incorporating the best available science as well as the broader context of historic land use, and economic, administrative and legal frameworks influencing the contemporary Poudre River. Therefore, instead of describing native conditions, the RHAF's recommended ranges describe conditions that would ensure a functioning, resilient river that meets critical water quality and ecological health thresholds and continues to perform the watershed services valued by the City of Fort Collins community.

The RHAF uses an academic grading scale (A, B, C, D, and F) to relate the sense of health or impairment in a way that is designed to be easily understandable. Grading guidelines provide specific criteria to describe the existing condition and/or magnitude of dysfunction to warrant a given grade. Each indicator and its metrics can be quantitatively evaluated, but lacking specific data, metrics can be assessed using best professional judgement following the established grading guidelines.

While a substantial amount of data already existed to inform RHAF, current data gaps for some of the indicators prevent the City from fully understanding the current condition of the river. To remedy this, the RHAF will form the basis of a City initiative to develop a **State of the River Assessment and Report** (2016). This long-term monitoring program will strengthen the City's ability to realize its vision of a healthy and resilient river, by tracking trends and detecting responses to management actions. The State of the River Report Card will also provide a clear, consistent and common means of communication within the City organization and the community.



Contents

I Introduction

Why Develop a River Health Assessment Framework?

The Cache la Poudre River (hereafter Poudre River or "River") is a treasured community asset. The City of Fort Collins (hereafter "City" or "CFC") recognizes that the Poudre River provides the community with a broad set of ecological, agricultural, municipal, industrial, and recreational benefits valued by the community.

The purpose of this River Health Assessment Framework (RHAF) is to articulate clearly defined goals for the river and provide a framework for monitoring progress towards meeting the goals. Given the central importance of the river to the community, the City has many initiatives underway to support the vitality of the river ecosystem. These extensive and diverse set of river-related efforts includes pollution prevention and stormwater management; regulatory compliance and water quality monitoring; conservation and restoration of urban streams, the river and its floodplain; augmentation of in-stream flows; ecological studies; and source water protection. While the purpose of each of these efforts is to benefit some aspect of river health, the City lacks a comprehensive, metrics-based framework to guide the overall vision for the river ecosystem.

Further, numerous City and community-adopted planning documents reflect broad support for maintaining a *healthy and resilient Poudre River*. Yet, in spite of the fact that there is an ever-increasing body of research available to help quantify the physical, chemical, and biological components of the river, the terms 'healthy' and 'resilient' are subject to various interpretations and have yet to be defined from the City's perspective.

The Poudre River basin is no exception to an era of highly altered and managed river ecosystems coupled with high demands for consumptive water. This document describes the rationale for establishing recommended ranges for the health and functioning of the river. It does so within the Poudre River's modern context as a working river with multiple beneficial uses – from delivery of water to towns and farms, to providing habitat, flood protection, and quality of life for the community. This framework builds upon similar tools from around the globe that include ecological factors which, when communicated collectively, provide a broad picture of river and watershed health. The RHAF evaluates river health using a 'report card' style format for effectively communicating the results of monitoring complex systems.

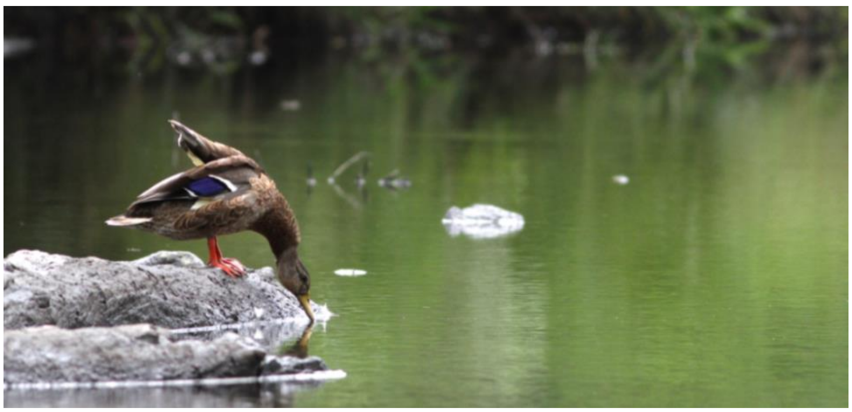


Photo by Norm Keally

Project Goal and Approach

The goal of the RHAF is to develop a framework to clearly describe the City's aspirations for a healthy and resilient Poudre River. The framework will help assess, guide and inform the City's efforts to support and sustain the health of the river.

This approach is supported through four components:

1. An **interdisciplinary City team**.
2. Alignment of the team around the common purpose of the **watershed services** and related **City objectives** to assure the pursuit of river health within an inclusive context.
3. Development of river health **indicators and associated metrics**.
4. Development of **recommended ranges** for each metric that if met or maintained indicate the river's health is sufficient to support the desired level of function and resiliency.

Geographic Scope

The RHAF is designed to be used throughout the Poudre River as it affects the City, from its headwaters to Windsor. In application, considerably more detail will be included for the reach extending from the City's water supply intake in the lower Poudre Canyon to I-25. The RHAF takes into account factors such as the effects of the upstream watershed, despite the fact that some of these factors fall outside the City's control.

Related Poudre River Research, Monitoring and Standards

The City is in the fortunate position of having a considerable amount of data and benefitting from numerous scientific studies of the Poudre River. To the extent possible and where applicable, this framework incorporates existing monitoring programs, data, and other ecological studies specific to the Poudre River. Where applicable, it refers to water quality and aquatic life standards established by the Colorado Department of Public Health and Environment (CDPHE). Key projects that have informed this framework include: the Source Watershed Monitoring Program (water quality); the Lower Poudre Monitoring Alliance (water quality, aquatic insects, and fish); the Ecological Response Model (ecosystem relationships)(City of Fort Collins, 2014); CFC Natural Areas breeding bird survey, hydrologic and hydraulic models (various gages, models, sources); and Colorado Parks and Wildlife fish monitoring data, land use and landform data (data primarily based in Geographic Information System).

Additionally, in the Urban Stream Health Assessment for the Fort Collins (City of Fort Collins 2012), urban tributaries were examined for their susceptibility to channel erosion, stream habitat, and channel geomorphology using a variety of established measuring and rating techniques. While the assessment methods completed for the RHAF are not identical to the Urban Stream Health Assessment, the approach and tools used in each are similar enough that the information yielded by each will be complementary.

Laying the Groundwork for the State of the River Assessment and Report Card

In addition to the goals set forth above, this framework plays two important and unique roles in the City's management of the River. First, it organizes a large amount of information into a single communicable form. Second, it will serve as the foundation for an upcoming comprehensive assessment of the river's condition by establishing a Poudre-specific assessment methodology. In the 2016 State of the River project, City staff will conduct the first complete river assessment and communicate the results through a State of the River Report Card. The City plans to repeat the State of the River assessment every 3-5 years and update the report card based on those findings to track trends in the river's health and document improvements and identify emerging health issues. This program will also enable the City to benchmark current conditions for each river reach against the recommended ranges.

II Integrating River Health within the Broader Context of City Interests

The interdisciplinary approach to developing the RHAF was the result of recent efforts by the City to align its river management priorities and interests. The City recognizes the inherent competing challenges, as well as the synergies, between securing a stable water supply, managing stormwater and flood risk, and restoring and maintaining an ecologically healthy river. The City also recognizes the River is a complex, interconnected system, with each department focusing on different aspects of the system and no single department being charged with managing the river system as a whole. Thus, this framework has relied on a collaborative, interdepartmental process to articulate what a 'healthy river' means in terms of the City's mission and to better understand the ways in which the City's River-related projects support or strain the health of the River.

City of Fort Collins Natural Areas Department Photo

Watershed Services and Related City Objectives

River health serves as an index to watershed health. Understanding the health of our river provides insight into the health of our watershed. A healthy watershed provides direct and indirect benefits to the communities living in the watershed. For the purposes of this project, these benefits are referred to as 'watershed services' (Figure 1). This project recognizes five essential categories of natural watershed services:

1. Clean water (in the river itself, and for the City's water supply)
2. Recreation, health and wellness for the community
3. Reliable water supply
4. Stormwater conveyance and floodplain resilience
5. River ecology

City of Fort Collins Natural Areas Department Photo

The City has a variety of programmatic objectives intended to maximize the benefit from these watershed services. While some City priorities, such as river ecology and water quality, have a synergistic, mutually supportive relationship, there are inherent tensions between others, such as maintaining river health while securing adequate water supply and safely conveying stormwater or effluent. To better understand the ways in which an assessment of river health may implicate the City's other needs and objectives, Table 1 sets forth the City's river-related objectives for each watershed service.

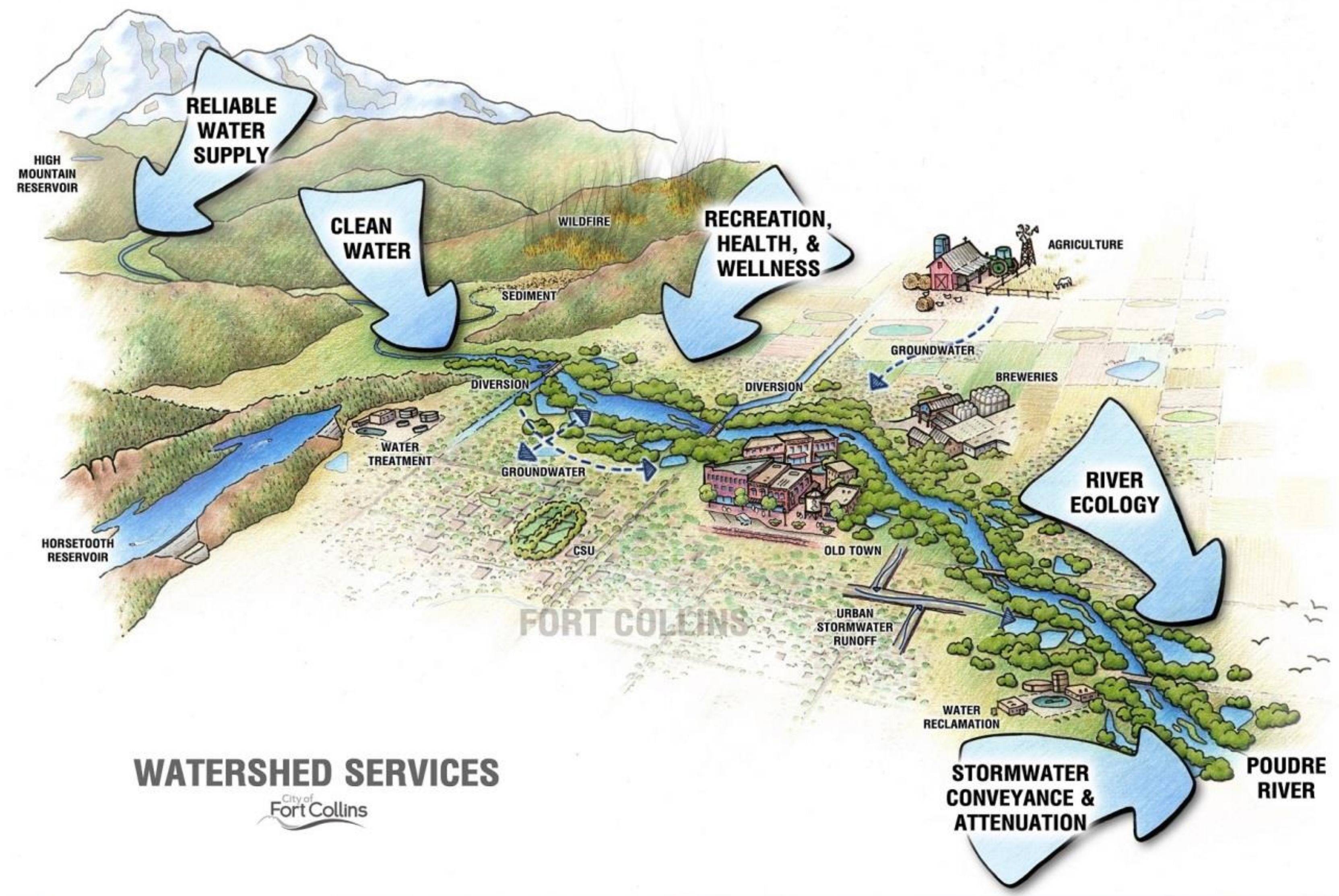


Figure 1: An illustration of the Watershed Services provided by a healthy Poudre River highlighting the interactions amongst natural features, community needs and challenges to river health.

Table 1: City-Wide Objectives Related to Five Watershed Services

Clean Water	
1	The Poudre River water supply remains **treatable with current technologies** to current drinking water **standards.**
2	Water quality conditions are **consistent** and do not significantly deviate from the expected seasonal and annual variability.
3	Poudre River fish and benthic populations are not significantly adversely affected by **pollutants** in urban runoff.
4	The Poudre River is protected against **discharges that are toxic** to humans, animals, plants and aquatic life.
5	Permitted discharges meet **water quality standards** to support established **beneficial uses** of the Poudre River.
6	The Poudre River is protected from streambank erosion, channel incision, sediment deposition and **pollutant loadings from stormwater runoff.**
Reliable Water Supply	
7	Poudre River streamflows are adequate to **reliably supply** a portion of the City's current and future **water demands.**
8	Water rights **administration** and storage operations are conducted to benefit Poudre River streamflows while first meeting City water demands and legal obligations.
9	**Surplus water lease**s are arranged to recover revenue for Utility ratepayers while also promoting agriculture in the Poudre Basin and, where possible, benefiting Poudre River streamflows.
Stormwater Conveyance and Floodplain Resilience	
10	Stabilize sections of the Poudre River constrained by existing urban activities in order to minimize infrastructure damage and public safety impacts.
11	Flood resilience is maximized while supporting multiple community land use objectives.
12	Effectively and safely **conveys** flood flows in accordance with current City/State/Federal floodplain regulations.
Recreation, Health & Wellness	
13	**Connect the community** to the river corridor by offering events, educational activities, interpretive features, and volunteer opportunities.
14	Preserve and interpret the **cultural and historic resources** within the river corridor.
15	Promote a healthy riverine environment as a place to **escape** from urban stresses, observe wildlife, and improve human health and wellness.
16	Promote community health and wellness by providing **recreation infrastructure improvements** to the river such as access points, instream recreation features, parks, and trails.
River Ecology	
16	Ensure **flows** are sufficient to sustain critical ecosystem functions and processes, including inundation of the riparian zone, refreshing the riverbed and supporting aquatic life.
17	To the extent possible manage **sediment and chemical inputs** to provide high-quality riverine habitats
18	Promotes a **river and floodplain shape** in balance with variability of flows, ecosystem dynamics, local infrastructure and safety.
19	Healthy, resilient and well connected **aquatic and riparian habitats** and **associated characteristic biota** are supported, maintained or restored.

III The Assessment Framework

The following section describes the main components of the framework, the river sections covered, and the methods used.

Outline of Framework

The River Health Assessment Framework includes ten ***indicators*** of river health (Table 2). Each indicator is evaluated by one or more ***metrics***. Each metric is assigned a recommended range of conditions for achieving a functional and healthy river.

Table 2: A summary of the Framework's river health indicators and the metrics used to measure and describe them.

Indicator	Metrics
Flow regime	Peak flow Base flows Rate of change
Sediment	Land erosion Channel erosion Transport
Water quality	Temperature Nutrients pH Dissolved oxygen
Floodplain connectivity	Extent Saturation duration
Riparian condition	Vegetation structure and complexity Habitat connectivity Contributing area
Debris	Large wood Detritus
River form	Planform Dimension Profile
Channel resilience	Dynamic equilibrium Channel recovery
Physical structure	Coarse scale Fine scale
Aquatic and Riparian Wildlife	Aquatic insects Native fish Trout Aquatic habitat connectivity Birds

River Sections

In order to develop meaningful, section-specific recommended health ranges, the study area was divided into four *stream sections* for this project. These sections were determined based on natural changes in river and valley type, topography, land use, and stream classifications, as designated by the CDPHE. In the future State of the River studies, these segments will also be used to stratify detailed sampling and monitoring efforts. The river sections for the RHAF are defined below and illustrated in Figure 2.

- **Canyon**: The headwaters of the Poudre River in Rocky Mountain National Park to the mouth of the Poudre River Canyon.
- **Transition**: The Poudre River from the mouth of the Poudre River Canyon to Shields Street in Fort Collins.
- **Urban**: The Poudre River from Shields Street in Fort Collins to the confluence with Boxelder Creek.
- **Warm:** The Poudre River from the confluence with Boxelder Creek to downstream of the confluence with Fossil Creek at County Road 32 East.

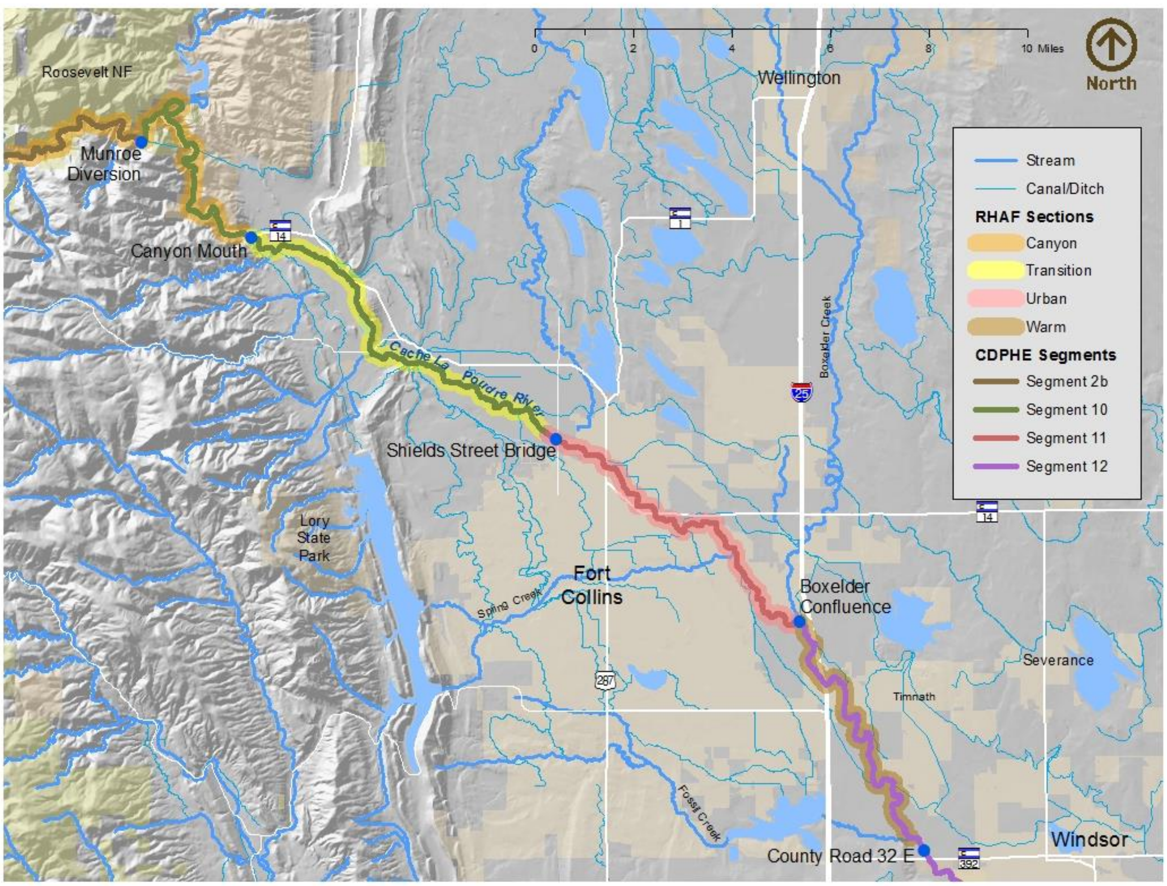


Figure 2: This map provides and overview of the geographic scope of the RHAF. It shows the Poudre River divided into four sections for purposes of this project and how those sections correspond to Colorado Department of Health and Environment regulatory segments.

RHAF River Sections Compared to CDPHE Regulatory River Segments

The CDPHE Water Quality Control Division (CDPHE/WQCD) uses a regulatory framework for classifying and assigning water quality standards to surface waters. Because aspects of the CDPHE regulatory framework are incorporated into the RHAF, it is necessary to understand the relationship across RHAF river sections and CDPHE classification of stream segments. The Poudre River, within the geographic scope of this project, is classified into three stream segments as defined by the CDPHE/WQCC's Regulation No. 38. The 'Canyon' river section downstream of Munroe Diversion and 'Transition' river section are classified as stream segment 10. The 'Urban' and 'Warm' river sections are classified as stream segments 11 and 12, respectively. The Canyon section upstream of the Munroe Diversion is classified into three stream segments (1, 2a, and 2b), with segment 1 beginning at the headwaters in Rocky Mountain National Park. Stream segment 12 continues downstream of County Road 32 East to the Poudre River's confluence with the South Platte River.

A Holistic, Functional Approach to Measuring River Condition

Defining a methodology for assessing river health is a precursor to setting recommended ranges for specific metrics, such as the condition of native fish or aquatic insect populations. In ecology, like medicine, the notion of health is related to the ability of the entity to perform vital functions. In the case of aquatic ecosystems, the functions performed by healthy rivers support watershed services that have both intrinsic and economic value. This framework defines river 'health' in terms of functional condition.

The physical, chemical and biological environment of the River creates the beneficial functions on which the community depends. The natural functions and ecosystem services provided by aquatic habitat are only provided by a healthy and resilient river system. Some functions, such as flood reduction, water quality maintenance, fishery support and sediment transport, are well known benefits of a healthy riverine environment. Other functions, such as food chain support or nutrient cycling, are more subtle, while just as important.

Functional assessments of rivers, streams and wetlands are designed to evaluate and describe the functional condition or health of aquatic habitats. The Functional Assessment of the Colorado Streams (FACStream) is one such functional assessment methodology (M. Beardsley, pers. comm. Jan. 10 2015). Because it was developed specifically for the purposes of assessing and describing the functional condition of Colorado's rivers, the City chose FACStream as the template for developing the City's River Health Framework. The FACStream framework is built from ten natural "state variables" (called "Indicators" in the RHAF) that drive river functioning. When evaluated collectively, these Indicators comprehensively describe river health by diagnosing the severity, extent and causes of river dysfunction.

The RHAF, building on the FACStream template, is intended to encompass the full spectrum of functions performed by the River. The FACStream employs common ecological principles and focuses on key ecological factors known to act together to generate all aquatic habitat functions. The performance of individual functions is assumed to follow the condition of the natural infrastructure used to produce these functions. Appendix A presents the changes made from the FACstream to the final RHAF.

Guiding Concepts

Several fundamental principles or 'guiding concepts' of modern river systems underlie the recommended ranges embodied in this report. These principles are essential to understanding and building the resilience of the River and community in the face of major disturbances such as floods, fires and drought. They include:

Variability of flows
Disturbance
Biodiversity
Watershed condition
Novel ecosystems
Collaboration and partnerships

The concepts of variability of flows, disturbance, biodiversity and the watershed condition are recognized in river science as key attributes of natural river systems. It is necessary to understand and plan with these concepts in mind, not only because they are beneficial and critical drivers in the river health, but also because they may present challenges to the City and its need to supply essential services, such as water supply, transportation ways, and a safe and resilient floodplain.

Novel ecosystems are natural systems that have been fundamentally altered by human actions. The modern Poudre River is one such novel ecosystem. This reality underscores the importance of recognizing the 150 years of human alterations to the system. On account of these changes, the pristine, native river is not attainable. Therefore, rather than describing native conditions, the criteria for an "A" grade describe a self-sustaining system.

The Poudre River system crosses many jurisdictional and political boundaries. The City of Fort Collins is only one of many important organizations working to positively influence the river's future. Therefore, efforts to maintain and improve river health will only be effective if collaboration and partnerships are prioritized and integrated into the City's river management initiatives.

These six guiding concepts are explored further in Appendix B.

Grading Health

Following the FACStream framework and numerous other ecological assessment methods, RHAF uses an academic grading scale (A, B, C, D, F) to relate the state of health or impairment. Grading guidelines provide the criteria for the conditions or magnitude of impairment warranting a given grade. Table 3 below provides grading guidelines that describe the general level of condition embodied by each grade category. Within a given grade category, the range of condition varies within the bounds of the grading criteria. The variation in condition within grade categories is conveyed by adding pluses or minuses to the letter grades (e.g., B+ or B-).

Grading criteria are based the severity of stressors degrading the indicator and on the amount of maintenance required to sustain or improve habitat conditions. Required maintenance is a cornerstone concept in grading. A lack of required maintenance implies a sustainable, dynamic equilibrium in the system. Active maintenance is required to set various components of the natural system back on track when disequilibrium threatens system stability. The maintenance required to sustain a dysfunctional river system has both direct and intrinsic costs to the residents of Fort Collins.

FACStream's grading guidelines apply broadly to all Colorado streams and rivers and are written to guide rapid functional assessment. However, because the Poudre River has been the subject of long-standing and intensive study, many of the FACStream grading guidelines have been customized specifically to the Poudre River. Ranges are recommended in association with the specific grading guidelines for each metric. The specificity or degree of customization of the guidelines for each metric vary based on availability of existing data, as well as the need to distinguish between conditions on different river reaches.

Photo by Norm Keally

Grading Guidelines and Recommended Ranges

Table 3 below provides the grading guidelines developed to calibrate all of the metrics against a common description for each grade letter.

Table 3: Grading guidelines used to calibrate the grading criteria of health indicators and metrics

A	Reference standard	Condition of the variable is self-sustaining and supports functional characteristics appropriate to sustain river health. Limited management to sustain and protect this level of function given stressors from the modern landscape.
B	Highly functioning	The condition of the variable maintains essential qualities that support a high level of ecological function, yet there is some influence of stressors at a detectable, yet minor, level. Requires some limited management to sustain and protect against stressors. The variable retains its essential qualities and supports a high level of ecological function.
C	Functioning	The condition of the variable has been altered and/or degraded by stressors that substantially influence the variable's functionality. The variable still supports basic, natural, stream/riparian functioning. Management is likely required to support maintenance of the characteristic functional role of the variable.
D	Functionally Impaired	The condition of the variable is severely altered by stressors that impair the variable's ability to support characteristic functioning and the overall health of the river. Extensive, active management is required to support maintenance of this level.
F	Non-functioning	The condition of the variable is under the influence of massive deleterious alterations/stressors. The level of alteration generally results in an inability of the variable to support characteristic functioning or it otherwise makes the area biologically unsuitable.

Recommended Ranges

After establishing the above grading guidelines, recommendations were developed for each metric. The recommendations describe a range of conditions necessary to support varying degrees of river health, as indicated by the grading guidelines.

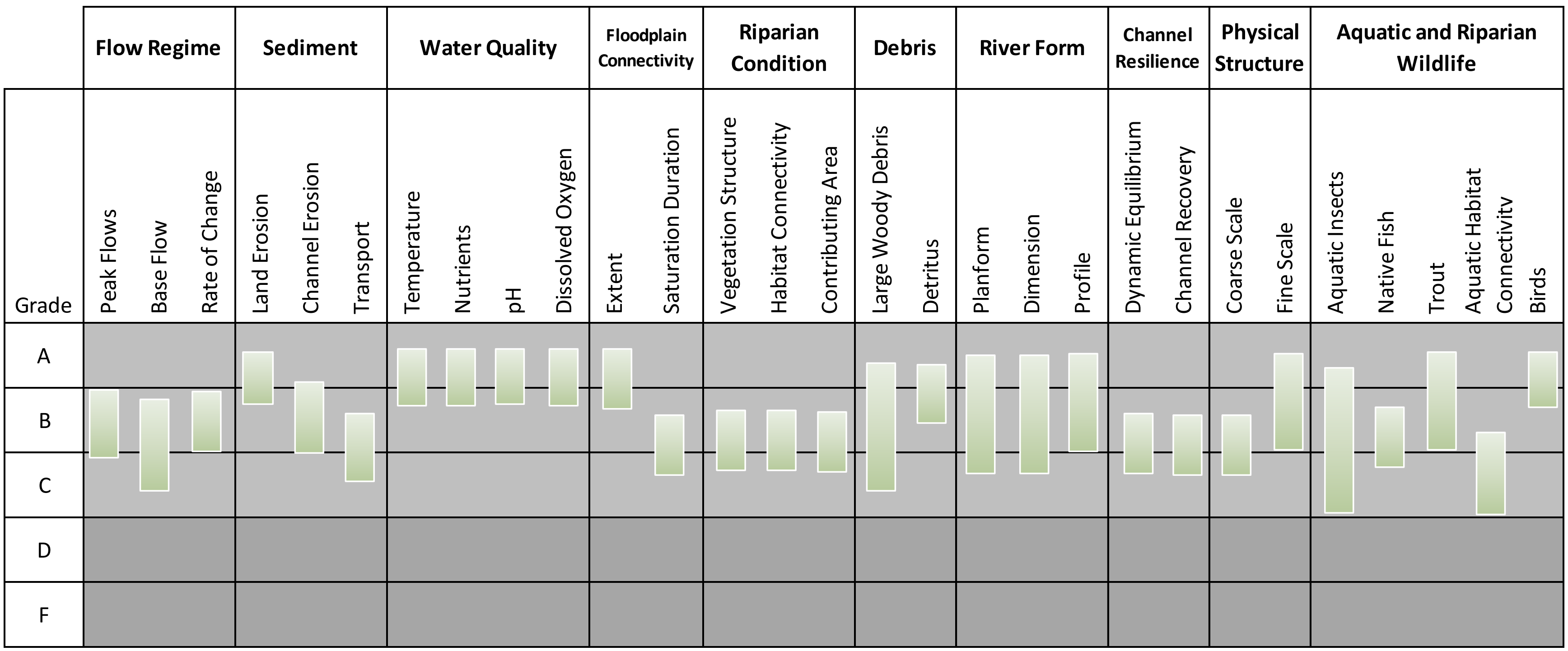
Recommended ranges consider not only the metric's direct support of river functioning but also the way it indirectly affects or suggests the condition of other health indicators. For example, aquatic insect populations not only perform intrinsic functions such as organic matter cycling, but they support fisheries and are indicative of water quality.

While the recommended ranges suggest upper limits for each metric, a better grade is always acceptable. The recommended ranges show the span of metric condition that would support ecosystem function and is potentially attainable.

Summary of Recommended Ranges

The following graph provides a snapshot of the recommended ranges described in the previous pages. In keeping with the goal of this initiative to develop aspirational but reasonable recommendations for river health, grounded in the guiding concepts, the framework recommends most metrics should fall in the B range with a few exceptions.

Table 4: A summary of the RHAF's grade recommendations for each health metric.



Indicators and Metrics

The following pages set forth the ten indicators of river health, the metrics for each indicator, the specific grading guidelines and recommended range for each metric. Appendix C provides further background, reasoning and/or empirical justification behind each grading guideline.

Indicator 1: Flow Regime

Water is commonly said to be the master variable of a river system. The magnitude, duration, frequency, timing, and rate of change of river flow interact with the landscape to determine the types and levels of functions that the river performs. In other words, the condition of the Flow Regime is a fundamental driver and indicator of river health. Three metrics are used to describe the condition of the river's Flow Regime: Peak Flows, Base Flows, and flow Rate of Change.

Adequate Peak Flows are essential to river health and functioning. Spring snow-melt-driven Peak Flows drive the production of many watershed services including water quality maintenance, support of fisheries and riparian habitats, recreation and aesthetics. High flows flush accumulated sediment and algae from the system, leaving the substrate clean and increasing the oxygen in the water. They also maintain the shape of the channel, facilitate forest reproduction, and sustain groundwater connections that moderate stream temperatures.

Photo by Dave Leatherman

Base flows, on the other hand, are the low flows that occur during drier times of the year. They support aquatic life and habitat connectivity after the seasonal snows have melted. Base Flows are generally comprised of rainfall in the watershed and slowly percolating groundwater (also referred to as return flows). In more managed systems, flows may be augmented with reservoir releases, exchanges and water administration and groundwater from the urban corridor. Base Flows are critically important to river health since the raw material for aquatic life support – water – is at its lowest supply.

It is not just the amount of water that matters to river health. The flow Rate of Change has an influence on aquatic and riparian species. On the Poudre River, rapid fluctuations in river flow, especially in the low flow months, create a highly unnatural environment that is a significant stressor on aquatic insects and fish.

The following grading guidelines for Peak and Base Flows are provided as narrative descriptions. In some cases, the grading guidelines include numeric values where the narrative thresholds are supported by research specific to the Poudre River at given locations.

Tables 5-7: Grading guidelines for the three Flow Regime metrics: Peak Flows, Base Flows, and Rate of Change.

Peak Flows

<table>
<tr><th>Grade</th><th>Description</th></tr>
<tr><td>A</td><td>Peak flows[1] provide all the functions necessary for a healthy and resilient river ecosystem. Hence, other metrics require no additional management on account of flow functions, but they may require management on account of other urban/anthropogenic stressors. Peak flows in this category support all functions listed below in the ‘B’ category, with the added function of inundating the riparian area to supporting all floodplain functions.</td></tr>
<tr><td>B</td><td>Peak flows have been reduced or re-timed such that the associated functions are operating, but with a somewhat reduced capacity. Peak flows support the ‘B’ grade for dependent metrics such as: largely natural coarse and fine scale physical structure to support aquatic habitat, long-term dynamic equilibrium with occasional support, maintenance of river form with occasional support, and inundation of riparian forests and wetlands.
<table>
<tr><th>Location</th><th>3 day Magnitude[2]</th><th>Frequency[5]</th></tr>
<tr><td>Transition Section[3]</td><td>3300 cfs</td><td>1 in 3 years</td></tr>
<tr><td>Warm Section[4]</td><td>2100 cfs</td><td>1 in 3 years</td></tr>
</table></td></tr>
<tr><td>C</td><td>Peak flows have been reduced or retimed such that there is an increased risk of having an adverse effect on associated functions. Bed mobility should occur (though with less certainty than at the B level) given discharges of:
<table>
<tr><th>Location</th><th>3 day Magnitude[2]</th><th>Frequency[5]</th></tr>
<tr><td>Transition Section[3]</td><td>2700 cfs</td><td>1 in 3 years</td></tr>
<tr><td>Warm Section[4]</td><td>1550 cfs</td><td>1 in 3 years</td></tr>
</table></td></tr>
<tr><td>D</td><td>Peak flows have been significantly reduced or retimed past critical system thresholds, having a cascading deleterious effect on associated functions and dependent metrics. Examples include reaches below diversions that have fluctuating low regimes but severely attenuated peaks, flashy urban watersheds, or watersheds with major augmentation or withdrawal. Peak flows reach desired magnitude for bed sediment mobility, but occur too infrequently (less than 1 in 7 years) to provide required function. Sand and silt deposited in the reach are flushed with regularity (2 in 3 years).
<table>
<tr><th>Location</th><th>3 day Magnitude[2, 6]</th><th>Frequency[5]</th></tr>
<tr><td>Transition Section[3]</td><td>1750 cfs</td><td>1 in 3 years</td></tr>
<tr><td>Warm Section[4]</td><td>900 cfs</td><td>1 in 3 years</td></tr>
</table></td></tr>
<tr><td>F</td><td>Peak flow patterns do not resemble the natural hydrograph resulting in the near elimination of natural stream functions and likely require high levels of management in order to maintain a river acceptable to the public and resource managers. Examples include rivers with overwhelming augmentation or withdrawal.</td></tr>
</table>

[1] The term ‘Peak Flow(s)’ in this table includes the magnitude, frequency and duration of peak discharge.
[2] Daily average flow for three days in a year.
[3] Corresponds to the Ecological Response Model (ERM) reach 3a below Larimer and Weld Ditch.
[4] Corresponds to the ERM reach 7 Below the Boxelder Gage.
[5] Grade adjusts to a ‘+’ if frequency is less than q in 3 years and a ‘-‘ if frequency is greater than 4-7 years.
[6] Flow magnitudes for the D grade based upon the flushing of sand and finer material deposited on the channel bed (ERM).

Base Flows

Grade	Description
A	Base flow magnitude is ample to provide all the functions necessary for a healthy and resilient river ecosystem. There are no dry-ups or other significant stressors and aquatic life is never stressed by altered base flow.
B	Base flow magnitude is somewhat less than optimal, yet has minimal effects on stream function. Aquatic life is rarely (and never critically) stressed by altered base flow. Base flows support associated 'B' grade designation for the Water Quality metrics, in turn supporting habitat availability and functional needs of aquatic life. Additionally, this grade levels requires winter daily average of 35 cfs, and all daily average flows are above 20 cfs[1].
C	Base flow magnitude alterations are short in duration, or are during times of the season when stream functions are minimally stressed. There are no dry-ups and the average base flows support aquatic life needs most of the time. Overall aquatic life is not stressed, despite spatially intermittent and temporally periodic areas of poor habitat availability and water quality. Daily average charge needs to be greater than 20 cfs. Additionally, during summer/fall there should be no impairment for dissolved oxygen (see 'C' grading guidelines for the Dissolved Oxygen indicator).
D	Altered base flow patterns are common and measurably affect stream function, such as multi-day periods of critically low flow or no flow. Winter daily average below 20cfs and short periodic of dry-ups occur in spatially limited sections. Summer/fall flows impaired for Dissolved Oxygen (see 'D' grade for Dissolved Oxygen).
F	Altered base flow patterns have critically reduced stream function, including eliminating native or desired species, violating water quality standards, and/or other irreversible changes. Examples include naturally perennial streams that regularly dry up, reaches where critically low flow conditions exist for most of the season, or dry-ups occurring at multiple longer reaches for extended periods of time.

[3] Corresponds to values contained in the Ecological Response Model (ERM).

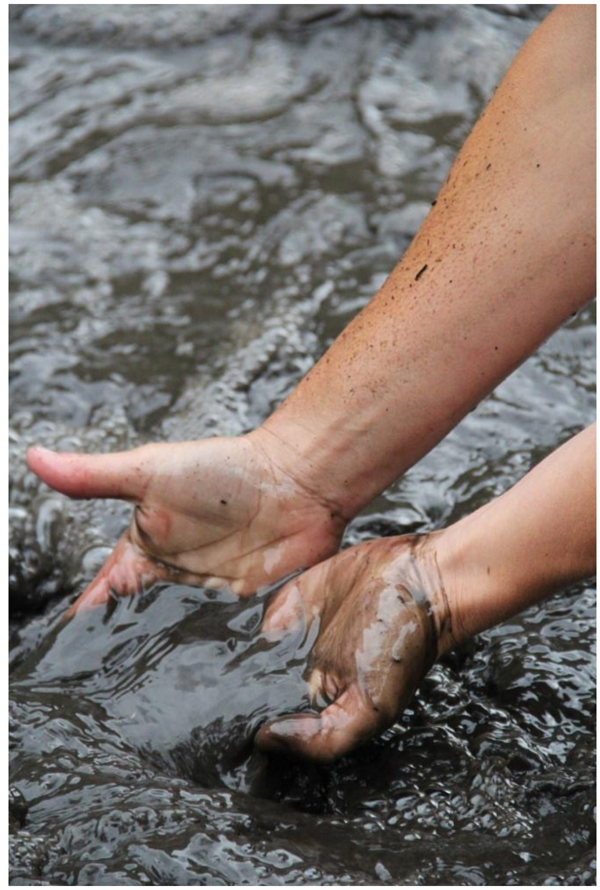
Rate of Change

Grade	Description
A	Flow rate of change equal to or less than that caused by natural weather patterns and seasonal trends. Rate of change is within the tolerance of native and desired biota.
B	Flow rate of change is somewhat altered but change over hours is slow enough to support highly functional aquatic life and abundant ecological diversity. This includes rate of change from peak flows (the descending limb of the hydrograph) as well as base flows.
C	Flow rate of change is moderately altered and stresses native and desired plants and animals. Daily flow change needs to be less than an order of magnitude per day to maintain this level of function.
D/F	Daily and hourly variability are erratic and independent of season or climate. Aquatic life is still able to exist, but only the most resilient species survive.

Recommended Ranges:

Peak Flows: B+ to B-
Base Flows: B+ to C
Rate of Change: B

Indicator 2: Sediment



Photos (left) City of Fort Collins staff (right) by Lucas Mouttet

Sediment is soil, sand and rock that is washed from the watershed slopes into the river. Fine sediments can be suspended in the water or larger particles can move along the river bed. Sediment is a natural component of the Poudre River ecosystem, but too much or too little will throw the river's physical processes out of balance. When sediment is in excess, it builds up on floodplains, buries fish spawning habitat, suffocates aquatic insects, and aggrades the channel bed. A shortage of sediment can be equally detrimental for river health. The river is always trying to balance its energy inputs and outputs. When sediment is withheld from a river reach, the excess energy of the water energy is expressed elsewhere such as through down-cutting into the bed or erosion of banks. In this way, a sediment-starved river finds its own sediment sources, but at a cost.

The Sediment indicator is described with three metrics: <u>Land Erosion</u>, <u>Channel Erosion</u> and sediment <u>Transport</u>. <u>Land Erosion</u> considers the amount of sediment produced in the watershed by hill slope processes and land uses resulting in exposed soils. <u>Channel erosion</u> evaluates sediment production caused by erosion of the channels of the river and its tributaries. While erosion is a natural process, the rates of erosion can be elevated by human activities, such as when alluvial streams incise to form gullies. Reductions in sediment <u>Transport</u> causes downstream areas to either become unstable due to bed and bank erosion or the sediments to armor the bed (degrading fish and insect habitats). Watershed contributions to sediment starvation include diversions, the construction of dams, excessive imperviousness in the watershed, or upstream channels being lined or buried in culverts.

Tables 8-10: Grading guidelines for the three Sediment metrics: Land Erosion, Channel Erosion and Transport.

Land Erosion

A	The amount and timing of sediment production from land erosion is relatively unaffected by human land use. There are no significant stressors.
B	Stressors are present but rates of surface erosion and mass erosion events appear to be mostly natural. Examples include watersheds with low road or development density or grazing practices that do not deplete vegetation cover. There is no visible discharge of sediment or evidence of sediment deposition from outfalls.
C	Land uses in the watershed are causing significant changes to the amount of land erosion. Examples include overgrazed slopes with increased bare ground, high density of unimproved roads, or evidence of past human-caused mass erosion. If present, visible discharge of sediment or evidence of sediment deposition from outfalls is minimal.
D	Greatly increased land erosion caused by human activity or land use is evident. Examples include widespread overgrazed or clear-cut slopes, erosion associated with roads adjacent to the stream, or evidence of recent human-caused mass erosion. Visible discharge of sediment or evidence of sediment deposition from outfalls indicates unprotected exposed soil in the contributing watershed.
F	Land uses in the watershed are causing an overwhelming amount of sediment from land erosion. Examples include widespread loss of ground cover on adjacent slopes with rill or gully formation or very large or frequent human-caused mass erosion. Visible discharge of sediment or evidence of sediment deposition from outfalls indicates a significant proportion of unprotected exposed soil in the contributing watershed.

Channel Erosion

A	Tributaries and main-stem rivers in the watershed show natural levels of erosion. There are no significant stressors.
B	Some tributaries and main-stem rivers in the watershed may have isolated areas of accelerated bank erosion, but channel-scale instability is not present. Stressors are present but the combined effects are minimal.
C	Accelerated bank erosion tributaries and main-stem rivers is common in the watershed. Localized areas with major instability, incision, and/or gully formation are present. The combined effects of stressors cause reach-scale instability which is moving through the watershed.
D	Accelerated bank erosion tributaries and main-stem rivers is widespread in the watershed. Human-induced channel erosion is a major source of sediment to the reach. Adjacent contributing reaches are incised and some of the contributing tributaries are unstable gullies.
F	Human-induced channel erosion is an overwhelming source of sediment to the reach. Stream and river reaches are unstable and many of the contributing tributaries are unstable incised channels or eroding gullies.

<u>Transport</u>

A	The amount of sediment delivered to the reach is at natural levels. This often can be attributed to a largely natural watershed, or the thoughtful application of best management practices which eliminate the impacts of watershed development.
B	Impediments to sediment delivery exist, but they are either insignificant or they block sediment from only a small portion of the overall contributing area. Watersheds may contain small diversion structures or larger dams located on small tributary drainages.
C	Impediments to sediment delivery are notable and block sediment from only a moderate portion of the watershed. Examples include small dams higher on the main stem or major dams on tributaries.
D	Major impediments to sediment delivery exist in the watershed, but these impediments either pass a portion of the sediment downstream or block sediment from a less than half of the contributing area. Reaches far below major dams are an example.
F	Major impediments to sediment delivery trap most or all incoming sediment, supplying the downstream reach with clear-water discharge. Examples include tailwaters below major dams.

Recommended ranges:

<u>Land Erosion:</u>	A to B+
<u>Channel Erosion</u>	B
<u>Transport:</u>	B to C

Indicator 3: Water Quality

Water Quality describes the ability of water to support life, including the plants and animals that live in it and those that depend on it, including humans. The notion of water quality encompasses element levels, such as those of lead or mercury, but it also refers to nutrient concentrations, pathogen concentrations, the amount of oxygen present, and the physical properties of water such as its temperature and pH. Four metrics are used to inform the Water Quality health indicator: Temperature, Nutrients, pH, and Dissolved Oxygen.

Water Temperature is a critical abiotic habitat factor that has a strong control on what types of organisms can inhabit a river reach. For instance, most species of trout are considered "cold water" fish. Viable populations cannot typically be sustained above a given temperature threshold. Nutrients in the water are necessary to support aquatic life, but when nutrients are supplied in excess, water quality suffers through algal blooms, decreased clarity, and bad odor. The pH of water is a measure of its acidity or alkalinity. Aquatic organisms react strongly to gradients in pH and it sets the context of the chemical environment mediating the types and rates of a host of bio-geochemical processes and reactions.

Like the air we breathe, the oxygen dissolved in water is essential to aquatic life. The Dissolved Oxygen content is generally high in steep mountain streams, where turbulent flows engulf "pockets" of air, allowing the gas to dissipate in the water. All other things being equal, dissolved oxygen content tends to decrease as flow rate decreases. Dissolved oxygen content is most commonly impacted by the elevated microbial respiration resulting from the decomposition of organic matter, such as over-growth of algae and aquatic plants.

Water Quality grading guidelines were developed using historical data collected by the City of Fort Collins Utilities' water quality monitoring programs and CDPHE water quality standards. Statistical and data analyses were performed on long-term data records to assess and compare data distributions over the period of record, 2009 to 2013.

City of Fort Collins Natural Areas Department Photo

Tables 11-14: Grading guidelines for the four Water Quality metrics: Temperature, Nutrients, pH and Dissolved Oxygen.

Temperature

A	Natural temperature regime is present. The annual and/or seasonal average water temperature is less than the 50th percentile.
B	Stressors are present but the combined effects are minimal. Examples include watersheds with relatively minor impacts to water source, floodplain connectivity, stream morphology, or riparian vegetation. Most headwaters reaches will score in this range or higher. The annual and/or seasonal average water temperature falls between the 50th and 75th percentiles.
C	The temperature regime is altered, but natural biotic communities are still mostly intact. Examples include reaches with widespread land uses that affect temperature, or reaches associated with moderate point source impacts such as small reservoirs. The annual and/or seasonal average water temperature is greater than or equal to the 75th percentile, but does not exceed the water quality standard.
D	The temperature regime is clearly altered, and impact to the distribution and abundance of characteristic aquatic life is documented or suspected. Tail waters below large reservoirs and 303d listed reaches should also be scored in this category or lower. The water quality standard has been exceeded.
F	The temperature regime is fundamentally altered by anthropogenic stressors, with effects on the distribution and abundance of characteristic aquatic life. The water quality standard has been exceeded consistently.

Nutrients

A	Natural physicochemical conditions exist. The annual and/or seasonal average is less than the 75th percentile.
B	Significant stressors are present but the combined effects are minimal. Examples include rural watersheds with low density land use or high density land use and buffers. No severe point sources are present. The annual average falls between the 75th percentile and the water quality standard.
C	The supply of organic material and/or nutrients is significantly altered but natural biotic communities are still mostly intact. Examples include reaches with significant agricultural or urban runoff or the presence of large reservoirs in the watershed. The annual and/or seasonal average is greater than or equal to the water quality standard, but does not exceed a 1-in-5 year exceedance frequency.
D	The supply of organic material and/or nutrients is clearly altered by anthropogenic stressors and impact to the distribution and abundance of characteristic aquatic life is documented or suspected. 303d-listed reaches should be scored in this category or lower. The water quality standard has been exceeded.
F	Unnaturally eutrophic or oligotrophic conditions clearly affect the distribution and abundance of characteristic aquatic life. The water quality standard has been exceeded consistently.

pH (measure of acidity)

A	Natural water quality conditions exist. The annual and/or seasonal average pH is within one standard deviation of the long-term mean.
B	Significant stressors are present but the combined effects are minimal. The annual and/or seasonal average pH is within one and two standard deviations of the long-term mean.
C	Water quality conditions are significantly altered but natural biotic communities are still mostly intact. The annual and/or seasonal average pH is within two standard deviations of the long-term mean and the water quality standard.
D	Water quality is clearly altered by anthropogenic stressors, and impact to the distribution and abundance of characteristic aquatic life is documented or suspected. 303d-listed reaches should be scored in this category or lower. The water quality standard has been exceeded.
F	The physicochemical environment is fundamentally altered by anthropogenic stressors, and conditions clearly affect the distribution and abundance of characteristic aquatic life. The water quality standard has been exceeded consistently.

Dissolved Oxygen

A	Natural water quality conditions exist. The annual and/or seasonal average is greater than the 50th percentile.
B	Significant stressors are present but the combined effects are minimal. The annual and/or seasonal average is between the 25th and 50th percentiles.
C	Water quality conditions are significantly altered but natural biotic communities are still mostly intact. The annual and/or seasonal average is within the 25th percentile of the water quality standard for aquatic life.
D	Water quality is clearly altered by anthropogenic stressors and impact to the distribution and abundance of characteristic aquatic life is documented or suspected. 303d-listed reaches should be scored in this category or lower. The water quality standard for aquatic life has been exceeded.
F	The physicochemical environment is fundamentally altered by anthropogenic stressors, and conditions clearly affect the distribution and abundance of characteristic aquatic life. The water quality standard for aquatic life and recreation has been exceeded consistently.

Recommended ranges:

Temperature: A to B+
Nutrients: A to B+
pH: A to B+
Dissolved oxygen: A to B+

Indicator 4: Floodplain Connectivity

The channel's access or connection to its floodplain affects river health as much as it does the riparian ecosystem. When flows are higher than the channel can contain, the floodplain provides relief. The floodplain allows excess water to spread across the land. Vegetation, woody debris and complexity in the floodplain's topography help absorb the energy of rushing water. This allows the channel to maintain a stable shape and habitat features, while also providing a buffer to vital human infrastructure. At the same time, overbanking flood flows nourish the riparian zone, replenishing nutrients, recharging the aquifer, and rejuvenating the forest.

City of Fort Collins Natural Areas Department Photo

A healthy floodplain harnesses the power of flood flows. It allows water to wander through a defined habitat zone where its abundant energy can not only dissipate but also bring forth new life.

The Floodplain Connectivity indicator is described with two metrics: Floodplain Extent and Saturation Duration. In evaluating Floodplain Extent two aspects of the floodplain are considered: the High Frequency Floodplain and the Low Frequency Floodplain. The High Frequency Floodplain considers the width of the floodplain that is inundated by flows occurring 1 in 5 years. This "five-year floodplain" helps the system maintain year-to-year dynamic equilibrium, and this is the zone where most of the river's forests and wetlands are created and sustained. The Low Frequency Floodplain includes the width of the floodplain inundated in more extreme events, namely flows on a 100 year reoccurrence interval. Understanding the low frequency floodplain helps us evaluate the river's ability to absorb and recover from large floods. Where floodplains are narrow, communities can expect that the river and associated infrastructure will require routine maintenance and substantial reconstructing following large flows. Please note: The submetric for the Low frequency floodplain will be developed in the futurephase of this project (or during the 2016 assessment).

Saturation Duration describes the hydrologic regime for a specific location on the floodplain. The duration of soil saturation drives a whole host of processes and functions – from creating habitat for water-dependent plants and animals to geochemical cycling.

Tables 15-16: Grading guidelines for the two Floodplain Connectivity metrics – Floodplain Extent and Saturation Duration.

Extent

Grade	Description
A	No significant stressors. The width of the 5-year floodplain is greater than 100 m.[1]
B	The width of the 5-year floodplain width is between 75 to 100 m
C	The width of the 5-year floodplain width is between 50 to 75 m
D	The width of the 5- year floodplain width is between 25 to 50 m
F	The width of the 5-year floodplain width less than less than 25m

[1]The five-year floodplain width includes both sides of the channel but excludes the channel itself. The categories are based on expected average widths for a river section. Each RHAF River section is characterized by a large degree of variation including long reaches with narrow to non-existent floodplains and intermittent wider reaches.

Saturation Duration[1]

Grade	Description
A	The active floodplain retains a characteristic saturation regime supporting a mosaic of wetland and riparian species.
B	The saturation regime of the active floodplain is mildly altered but still supports a mosaic of wetland and riparian species.
C	The active floodplain still can become seasonally saturated for more than 14 consecutive days on the average of one out to two years, but saturation duration is substantially shorted from a characteristic regime. Wetland habitats tend to be dominated by facultative wetland species.
D	Saturation of the active floodplain happens less than once in two years on average, or for a period of time less than 14 consecutive days. Saturation is generally limited to depressions in the floodplain.
F	No functional floodplain exists.

[1]This metric retains the original language from the FACstream method. However, it is likely to be further developed in the process of the first field application (2016)

Recommended ranges:

Note: The following recommended range for "Extent" is intended to be applied at the landscape level (each of the four RHAF river sections). Thus, the recommended range is not the City's intent to manage each local property within the floodplain, rather an overall goal at the larger scale.

Extent: A to B
Saturation: B to C+

Indicator 5: Riparian Condition

The riparian zone is the area adjacent to and influenced by the river, especially its hydrology. The riparian zone can be very narrow in canyon reaches or extend for miles when unconfined. On the plains the riparian zone is characterized by a grand gallery forest of cottonwood, intermixed with meadows and wetlands. The ribbon of riparian habitat forms a virtual highway for wildlife and birds. Roughly 80% of Colorado's species are dependent on riparian areas for food, water and refuge. Riparian habitats flood at varying intervals depending on topography, flow regime and channel shape. While high flows cause disturbance to the habitat by uprooting trees, removing vegetation and burying plants with sediment, this flooding is actually central to the persistence of the riparian ecosystem.

The condition of the riparian zone is described using three metrics: Vegetation Structure and Complexity, Habitat Connectivity, and Contributing Area. Healthy riparian zones are characterized by a high level of vertical complexity, including the presence of tree, shrub and herbaceous vegetation layers. They are also patches. Vegetation Structure and Complexity is a result of shallow alluvial groundwater and the cyclic regime of disturbance caused by seasonal flooding. It influences a spectrum of river functions, from channel stability to evaporation. The importance of the structure and complexity of riparian habitat is perhaps most commonly associated with the critical role it plays in forming wildlife habitat.

The ability to move freely through the riparian corridor is of fundamental importance to animal and plant species. Regardless of the condition of a riparian patch, if it is functionally isolated, its value to wildlife greatly diminished. Habitat Connectivity in healthy riparian ecosystems allows unrestricted movement of wildlife laterally between habitat patches and up and down the corridor to other reaches. The Contributing Area is the landscape surrounding the riparian zone. Land uses adjacent to the riparian area can affect its function and condition, such as when nutrient-rich runoff causes shifts in species composition. Dysfunctions in riparian health in turn can affect the health of the river, potentially altering nutrient cycling, temperature, channel stability and aquatic biota.

Tables 17-19: Grading guidelines for the three Riparian Condition metrics: Vegetation Structure, Complexity and Composition, Contributing Area and Habitat Connectivity.

Vegetation Structure, Complexity

A	The structure, complexity and species composition of the riparian vegetation resemble native conditions. The weighted metric score is 100 – 90, indicating that vegetation is self-sustaining with an absence or trivial presence of noxious species, a strong predominance of native species without spread of aggressive species, and characteristic habitat patchiness and interspersion.
B	The structure, complexity and species composition of the riparian vegetation still resemble native conditions but with mild detectable changes. The weighted metric score is <90 – 80, indicating that vegetation is largely self-sustaining, requiring little maintenance to preserve habitat vegetation quality. Noxious species may be present but at very low densities that do not threaten functioning. Desirable native species predominate but minor invasion by aggressive species may be present. Habitats maintain a high degree of patchiness and interspersion, but some minor homogenization through land use has occurred.
C	Substantial changes in the character of the vegetation are evident, including alteration of layer coverage, structural complexity and species composition; but, the vegetation retains its essential character. The weighted metric score ranges between 70 - <80 indicating that regular minor management, such as weed spraying, is required to maintain vegetation condition. Minor populations of noxious species may occur, and a larger proportion of the species are exotic or aggressive native species. Homogenization of the riparian vegetation is common in terms of vertical structure or habitat interspersion.
D	The vegetation structure, complexity and species composition have been profoundly impacted. The weighted metric score is 60 - <70, indicating that significant patches of noxious weeds may be present, along with a preponderance of exotic species. Aggressive native species may wholly dominate the vegetation, substantially reducing vertical and horizontal vegetation complexity.
F	The vegetation layer has been completely removed or altered to the extent that is no longer comparable to the natural structure, diversity and composition. The weighted metric score 50 - <60.

Contributing area

A	No appreciable land use change has occurred on the surrounding landscape.
B	Some land use change has occurred in the surrounding landscape, but changes have minimal effect on the landscape's capacity to support characteristic aquatic functioning. This may be because the land use changes are not intensive, e.g., haying, light grazing, or low intensity silviculture, or because more substantial changes have occurred in less than roughly 10% of the area.
C	The surrounding landscape has been subject to a marked shift in land use; however, the land retains much of its capacity to support natural wetland function and is not an overt source of pollutants or sediment. Moderate-intensity land uses such as dry-land farming, urban "green" corridors, or moderate cattle grazing would commonly fall within this scoring range.
D	Land use changes in the surrounding landscape have been substantial, including a moderate-to-high coverage (up to 50%) of impermeable surfaces, bare soil, or other artificial surfaces. Considerable in-flow urban runoff or fertilizer-rich waters are common. The supportive capacity of the land has been greatly diminished but not totally extinguished. Intensively logged areas, low-density urban developments, some urban parklands, and many cropping situations would commonly result in a score within this range.
F	The surrounding landscape is more or less completely developed or is otherwise a cause of severe ecological stress on wetland habitats. Commercial developments or highly urban landscapes generally result in a score of less than 0.6.

Habitat connectivity

	Habitat patch size	Types and degree of barriers
A	A continuous corridor of functional riparian habitat > 100 m exists.	No appreciable barriers exist between the assessment reach and adjacent wetland and riparian habitats
B	A continuous corridor of functional riparian habitat 50 - 100 m wide exists.	Barriers impeding migration or dispersal between the assessment reach and adjacent wetland/riparian habitat are permeable and easily passed by most organisms. Examples could include gravel roads, minor levees, ditches or barbed-wire fences. More significant barriers (see "D" grading guidelines below) could affect migration of plant and animal species in the assessment reach to up to 10% of the surrounding wetland/riparian habitat.
C	A continuous corridor of functional riparian habitat 15 - 49 m wide exists.	Barriers to migration and dispersal retard the ability of many species to pass between the assessment reach and adjacent wetland/riparian habitat. Passage of species through such barriers is still possible, but it may be slowed down, constrained to certain times of day, increasingly dangerous or require additional travel. Busy two-lane roads, rail lines, small-to-medium artificial water bodies or widely scattered residential development would commonly result in a score in this range. More significant barriers (see "functioning impaired" category below) could affect movement to up to 10% of the surrounding wetland/riparian habitat.
D	A continuous corridor of functional riparian habitat 15 - 49 m wide exists.	Barriers to migration and dispersal preclude the passage of many types of species between the assessment reach and up to 66% of surrounding wetland and riparian habitat. Travel of those animals which can potential negotiate the barrier are strongly restricted and may include a high chance of mortality. Up to 33% of surrounding wetland/riparian habitat could be functionally isolated from the assessment reach.
F	A continuous corridor of functional riparian habitat is less than 5 m or absent altogether.	The assessment reach is essentially isolated from the surrounding wetland/riparian habitat by impermeable migration and dispersal barriers. An interstate highway or concrete-lined water conveyance canal are examples of barriers that would generally create functional isolation.

Recommended Ranges:

Vegetation Structure and Complexity: B to C+
Contributing Area: B to C+
Habitat Connectivity: B to C+

Indicator 6: Debris

The organic debris contributed by the riparian habitat to the channel is critical to river health as it provides habitat structure, influences channel form, and constitutes the foundation of the aquatic food chain. Dead-fall trees and large branches that become snagged in the channel or trapped on islands change the hydraulics of flowing water. This provides refuge for aquatic species and drives geomorphic processes that ultimately maintain the channel shape and bank configuration.

The Debris indicator is described by two metrics: Large Wood and Detritus. Large Wood is comprised of branches and trees which fall into the riparian area or channel. Large wood provides habitat diversity and organic material to both the riparian habitat and within the river channel. Detritus includes fine material such as leaves, small twigs, decomposing large wood, animal remains, and waste products. Detritus is the river's sources of organic material and the base of the river's food web feeding aquatic insects and subsequently trout and native fishes.

Tables 20-21: Grading guidelines for the two Debris metrics: Large Wood and Detritus.

Large Wood:

A	Large wood supply and presence is at natural levels for this river system. There are no significant stressors.
B	Stressors are present but the supply of large wood is not significantly affected. Examples include fetch areas with minor encroachment, minimal forest clearing, or recovering forests.
C	Large wood supply is significantly limited. Examples include reaches with woody riparian areas that are partially cleared or urban areas where large wood is removed for safety purposes and selective large wood is left in strategic locations within the channel.
D	Large wood supply is severely limited. Examples include cleared or developed riparian areas with very thin buffer strips, and urban areas with removal of most of the large wood in the channel and riparian areas for safety purposes
F	Large wood supply is essentially zero. Examples include riparian areas that are developed, converted from woody to grass or rivers from which all large wood is actively removed.

Detritus

A	Detritus supply is largely unaffected. Riparian vegetation maintains its characteristic structure and composition.
B	Vegetation changes in the riparian zone may exist, but stream side vegetation is largely intact and the amount and type of detritus is minimally affected.
C	Detritus supply is limited or altered in composition, such as by widespread clearing of woody species or partial isolation of the river from its floodplain. Sufficient detritus is still able to reach the channel to support faunal food webs.
D	Detritus supply is seriously limited in quantity, or its composition has been fundamentally altered. This can be caused by extensive row cropping, urban encroachment, vegetation clearing to the river's banks, or substantial isolation of the floodplain and river.
F	Detritus supply is severely limited or functionally nonexistent because of a widespread lack of stream side vegetation or total isolation of the river from its floodplain.

Recommended Ranges:

Large Wood: A- to C
Detritus: A- to B

Indicator 7: River Form

Understanding how the river form responds to human-caused and natural stressors is important for effective management, conservation, and rehabilitation of rivers and streams. For example, channel change may have implications for the protection of property and structures, water supply, navigation, and biotic and riparian habitat. Geomorphic responses to disturbances include changes to the channel bed elevation (erosion or deposition), channel width, channel form (e.g., braided, plane bed, riffle-pool) and/or the size of channel bed materials. While most channels tend towards an equilibrium state, it could be argued that no channel is truly in equilibrium and that channels are always adjusting to some short- or long-term influence. Fortunately this tendency toward equilibrium is intrinsic to river systems when the necessary building blocks of space, water, and sediment are present.

Planform refers to the 'bird's eye' view of the river and describes the degree of branching and sinuosity. The Channel Dimension focuses on the cross-sectional condition that can be altered by the processes of degradation, enlargement, and widening. Channel Profile is the downstream gradient or slope of a river, including any abrupt drops caused by dams or other grade control structures.

Tables 22-24: Grading guidelines for the three River Form metrics: Planform, Channel Dimension and Profile.

Planform

Grade	Description
A	Planform and variation is appropriate for a well-functioning river of this flow/sediment regime and landscape setting. There are no significant stressors to the river planform.
B	Planform and variation is appropriate for a river of this flow/sediment regime and landscape position. Stressors are evident, but with minimal effect on the river planform.
C	There are localized impacts to the river planform, possibly from floodplain encroachment or hardened banks.
D	There are widespread impacts to the river planform, from floodplain encroachment, hardened banks, or planform straightening.
F	Severe changes to the planform are evident. Examples include anastomosed or meandering streams that were straightened, or rivers with armored banks.

Channel Dimension

Grade	Entrenchment	Channel Cross Sectional Area	Width to Depth ratio
A	Not entrenched	Appropriate with no significant stressors	Appropriate with no significant stressors
B	Minimal entrenchment	Stressors present, but effects are minimal	Stressors present, but effects are minimal
C	Slight entrenchment	Slightly enlarged or reduced	Slight overwidth or overdepth
D	Moderate entrenchment	Enlarged or reduced	Overwidth or overdepth
F	Fully Entrenched	Extremely enlarged or reduced	Extreme overwidth or overdepth

<u>Profile</u>

Grade	Description
A	Overall water surface slope and bed profile variation are appropriate for a well-functioning river of this flow/sediment regime and landscape position. There are no significant stressors.
B	Overall water surface slope and bed profile variation are appropriate for a well-functioning river of this flow/sediment regime and landscape position. Stressors are evident but with minimal effect.
C	There are changes to the localized bed profile and/or the water surface slope is impacted to a small degree. Examples include reaches with small grade control structures (decreased slope) or reaches that have been slightly straightened (increased slope).
D	There are major local gradient impacts at low flow and/or significant changes to the slope of the water surface. Examples include reaches with large grade control structures and moderate planform changes.
F	Severe changes to slope are evident. Examples include anastomosed or meandering streams that were straightened, or streams with very large grade control structures.

Recommended ranges:
<u>Planform</u>: A to C+
<u>Dimension</u>: A to C+
<u>Profile</u>: A to B

City of Fort Collins Natural Areas Department Photo

Indicator 8: Channel Resilience

Like all rivers, the Poudre River faces major disturbance events including floods, droughts, and fires. To recover from these disturbances, rivers must rely on their built-in resilience. This resilience is a direct function of the availability of appropriate flow and sediment regimes, ample lateral space, connectivity to adjacent ecosystems, and the pre-disturbance condition of the system. The more rivers can be managed for resilience, the healthier they will be under common conditions, and recovery from major disturbances will be faster.

Dynamic Equilibrium is the long-term (decadal) tendency for a river to maintain its form or character under a characteristic flow and sediment regime. The definition of dynamic equilibrium varies for different river types. In channels where sediment does not tend to move, stability is a function of both the channel bed and the banks being stronger than the forces acting upon them. In other channel types, in which there is a balance of incoming and outgoing sediment, stability is maintained through a complex state of dynamic equilibrium between sediment supply and flow energy. The Channel Recovery metric describes the ability of a river system to rapidly recover from changes arising from singular extreme events or disturbance (e.g., floods, fires, landslides) in an acceptable length of time.

Tables 25-26: Grading guidelines for the two Channel Resilience metrics – Dynamic Equilibrium and Channel Recovery

Dynamic Equilibrium

A	Stressors are minimal. Patterns, levels, and rates of dynamic processes (erosion, deposition, and migration) are appropriate for the river in light of its landscape setting.
B	Moderate stressors are present but partially mitigated. Patterns of erosion, deposition, and migration are largely within the natural range for this river type.
C	Moderate stressors are present and largely unmitigated. Notable impacts to stability are evident (but not widespread). Examples of impacts include excess deposition, scour, bank erosion, accelerated migration, pool filling, unnatural bars, over-widening, enlargement, or mild incision.
D	Significant stressors are present and unmitigated. Excess deposition, scour, or widespread bank erosion are common., along with common avulsions on meandering streams, complete pool filling, reach wide aggradation, recent head cuts, or artificially hardened channels in unconfined alluvial valleys.
F	Streams have visible and rapid aggradation, incision, or migration. Stressors need to be identified and mitigated rapidly or the instability will worsen and spread.

Channel Recovery

A	Reach conditions indicate full resilience and capacity for rapid recovery. There are no significant stressors that would impede the physical movement/adjustment of the stream or the recovery of critical components.
B	Conditions indicate the reach retains the potential to be resilient to moderate events, but slow to recover from major events. The reach has a characteristically wide and attached floodplain, mostly native riparian vegetation, and few structural impediments to movement/adjustment. Moderate stressors are present but are either mitigated or minor.
C	Reach conditions indicate impaired capacity to be resilience to moderate events and difficulty in recovering from major events. Examples include structural impediments to physical movement/adjustment, slightly diminished floodplain connectivity, or vegetation that is limited due to a lack of local source material, impediments to establishment, or exotics.
D	The reach has very limited capacity to be resilient to episodic flood events. Examples include reaches that depend upon artificial stabilization or structures, have limited floodplain connectivity, have very poor riparian vegetation, or where water source impairment strongly affects peak flows and effective discharge.
F	The reach lacks the ability to rebound from and be resilient to episodic flood events, demonstrating little or no capacity for natural recovery from disturbance events. The stream relies completely on human-led restoration efforts. Examples include artificially maintained threshold channels, and reaches with severe floodplain disconnect, severely limited mechanisms for vegetation recovery, or a severely impaired water source.

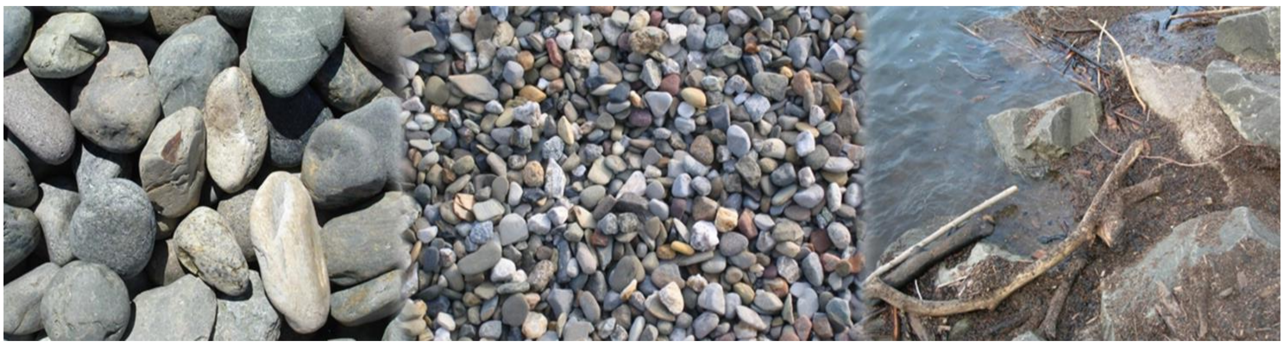
Recommended Ranges:

Dynamic Equilibrium: B+ to C+
Channel Recovery: B+ to C+

City of Fort Collins Natural Areas Department Photo

Indicator 9: Physical Structure

Physical structure in streams and riparian areas is the product of channel change, hydraulics, biological processes, and the work of natural ecosystem engineers such as beavers. As we alter the inputs or form of a stream corridor through land use changes, these actions have direct effects on the physical structure within that system. The required physical structure is often dictated by the habitat needs of native (or desired) species. Habitat needs vary widely by species and life stage. Diversity in physical structure supports a wider variety of species and/or life stages and provides places for aquatic species to rest or hide in times of stress. Diversity in physical structure tends to be difficult to maintain in highly static systems.



Coarse Scale Physical Structure includes the characteristic diversity of different water velocity conditions (fast versus still water), depth, and physical cover such as structural elements (e.g., large wood jams or rocks), overhanging banks, and vegetation for the selected reference condition. Factors affecting Coarse Scale Physical Structure include habitat types and distribution (e.g., pool spacing, pool-riffle ratios) and velocity/depth ratios. Fine Scale Physical Structure evaluates the amount and diversity of microhabitats within the reach, primarily bed materials and algae. Typical factors affecting fine-scale physical structure include bed material size distribution, fine sediment deposition and scour, embeddedness, compaction, and algae type/cover. Degradation can include channel bed armoring, elevated fine sediment deposition, or excessive algae.

Tables 27-28: Grading guidelines for the two Physical Structure metrics – Coarse-scale Physical Structure and Fine-scale Physical Structure.

<u>Coarse scale physical structure</u>

A	Natural coarse-scale structural heterogeneity on the reach is characteristic of the reference stream type. There are no significant stressors.
B	Mostly natural coarse scale physical structure is present. Examples include reaches with slightly altered physical structure arising from dispersed stressors or minimal direct impacts. Stressors are present but the combined effects are minimal.
C	Most typical velocity-depth combinations are present, but distribution of features is skewed. Examples include reaches with increased pool/run habitat or lack of off-channel habitat.
D	Some typical velocity-depth combinations or characteristic structural elements are absent, making the reach uncharacteristically homogenous. Examples include reaches with graded or heavily armored banks, or with features that are frequently limited by inundation or low flow.
F	There is severely altered coarse-scale structural diversity. Examples include reaches with severely homogenized physical characteristics such as unnatural plain-bed morphology.

<u>Fine scale physical structure</u>

A	Fine-sediment/algae flushing and bed mobility flow functions are intact, with the substrate clean on the surface and interstitial space open. Algae exists but is limited. Stressors are minimal.
B	Fine sediment/algae flushing occurs at least 2 in 3 years and bed mobility in at least 1 of 3 years. Interstitial space is open in high-energy zones such as riffles but showing some evidence of degradation. Stressors are present but the combined effects are minimal.
C	Fine sediment/algae flushing is partially intact, but bed mobilization flows are not present. This can result in reaches with moderate degradation, including patches of armoring/embeddedness or algae in the riffles.
D	There is partial-to-no substrate cleaning and channel maintenance is absent. Examples include gravel or cobble-bed streams with bimodal materials distribution, increased embeddedness, and reaches with excessive algae.
F	Completely static/armored conditions exist, possibly choked with fine sediment and/or algae, or because of no movement or flushing in past 5+ years.

Recommended Ranges:

<u>Coarse Scale</u>: B to C+
<u>Fine Scale:</u> A to B-

Indicator 10: Aquatic and Riparian Wildlife

The Aquatic and Riparian Wildlife indicator considers the composition of animal species that depend on the river and/or its riparian forests for their survival. Together, the different organisms form a "trophic" or feeding pyramid in which biota, such as aquatic insects, which are low on the pyramid, support animals such as trout, which are higher on the pyramid. Four metrics are used to assess this indicator: Aquatic Insects, Native Fish, Trout, Aquatic Habitat Connectivity and Birds.

Aquatic Insects are an essential component of the river ecosystem, performing numerous critical functions. Aquatic insects can act as an important barometer of water quality, providing early warning when negative trends are occurring. The Native Fish metric focuses on the small-bodied, warm-water species common to the eastern Colorado plains. These fishes avoid colder mountain waters and therefore are not expected upstream of Shields Street in Fort Collins. Trout are a hallmark of Colorado's streams and a valued recreational resource.

Aquatic Habitat Connectivity provides an indirect assessment of the health of aquatic life. Aquatic species must be able to travel among habitats to feed, avoid stressors, and breed. Barriers, such as cross-channel agricultural diversions, can hamper or outright block the movement of aquatic species, causing populations to suffer and breaking down faunal food webs.

Over 80% of all Colorado Birds use riparian habitats at some point in their life cycle. Some species depend entirely on riparian forests for critical breeding habitat. The presence of the types of species that inhabit structurally diverse riverside forests provides a gage of the overall quality of riparian forest as habitat.

The development of these wildlife metrics was informed by existing monitoring programs that provide data for a portion of the study area. Therefore, they are written with a focus on quantitative rather than narrative descriptions. Even so, each grade was developed with an intent to quantitatively reflect the function-based grading guidelines as presented in Table 3.

Photo by Aran Meyer

Tables 29-33: Grading guidelines for the five Aquatic and Riparian Wildlife metrics – Aquatic Insects, Native Fish, Trout, Aquatic Habitat Connectivity and Birds.

Aquatic Insects

A	The reach sustains and supports reference conditions for aquatic insect communities and aquatic life use. No management is needed other than protection of existing conditions. MMI[1] score is 80-100.
B	Some detectable stressors are likely with minor alterations to aquatic communities. The ecological system retains essential qualities and supports a high level of function. Some management may be required to sustain or improve this condition. MMI score is 65-<80.
C	The reach supports and maintains essential components of the aquatic ecosystem, but exhibits measurable signs of degradation and less than optimal community parameters. The reach meets the attainment threshold, with an MMI score of 52-<65.
D	There are detectable alterations or degradation of aquatic life use, but the system still supports a fundamental community structure and function. Active management is required (or at least recommended) to maintain and improve characteristic functional support MMI score is 42-<52.
F	There is clear impairment to benthic macroinvertebrate communities and aquatic life. This level of alteration generally results in an inability to support characteristic benthic organisms, or makes the stream segment biologically unsuitable. The reach has a "below impairment" threshold with an MMI score of <42.

[1] Data is available only for Lincoln Street downstream. MMI (multi-metric index) is established by the CDPHE and explained further in Appendix C. Scores and thresholds are established according to biotype.

Native Fish[1]

A	12 or more taxa, multiple life stages for most species
B	9-12 taxa, multiple life stages for most species
C	7-8 taxa, multiple life stages for half of species
D	5-6 taxa, single life stage for most species
F	4 or fewer taxa, single life stage for most species

[1] These fishes do not thrive in colder mountain waters and therefore are not expected upstream of Shields Street in Fort Collins. Data was collected in the transition and warm water reaches. The grade has been trending downward over time as observations of plains top minnow, brassy minnow and red shiner have been increasingly rare over the past decade.

Trout

A	Population shows 4 age classes present; high levels of natural reproduction and age 0 fish documented; high total biomass (60lbs+/acre-gold medal standard); overall average relative weight is average or higher than average; viable recreational fishery, many adult fish. More cold water obligate trout species (rainbow and cutthroat trout) present and reproducing.
B	Population shows 3 age classes present; medium levels of natural reproduction and age 0 fish documented; medium total biomass (40-59lbs/acre); overall average relative weight is average; mediocre fishery with moderate numbers of adult fish.
C	Population shows 2 age classes present; low levels of natural reproduction and age 0 fish documented; low total biomass (20-39lbs/acre); overall average relative weight is below average; inconsistent recreational fishery with low numbers of adult fish
D	Population dominated by a single age class; very sporadic natural reproduction and few age 0 fish documented; very low total biomass (0-19lbs/acre); overall average relative weight is substantially below average; minimal recreational fishery potential with very low numbers of adult fish
F	No trout present; no natural reproduction; no biomass; no recreational fishery

Aquatic Habitat Connectivity[1]

A	20 miles connected
B	10 mile segments
C	5 miles segments
D	2 miles segments
F	1 miles segments

[1] Native fish habitat requirements are less well understood compared to brown trout which are known to travel over 20 miles. Even without specific research on the native fishes, stream fishes in general need to be able to move among a mosaic of habitat types in order to be resilient under adverse conditions.

Birds

A	91-100% of Indicator Species[1] present during the breeding season dependent on native heterogeneous habitat structure dominant (>90%), Management needed as directly related to sustaining current conditions.
B	71-90% of Indicator Species present during breeding season, reflecting habitat structure strongly native and heterogeneous (70-90%).
C	51-70% of Indicator Species present during breeding season, reflecting habitat that consists mostly of native plants (50-70%) and there is limited heterogeneity in structure.
D	31-50% of Indicator Species present during breeding season, reflecting habitat lacking in native plant diversity (30-50%) and habitat heterogeneity.
F	0-30% of Indicator Species present, reflecting habitat severely lacking in native plant diversity (0-30%, mostly dominated by non-native plants) and habitat structure is homogeneous.

[1] The City of Fort Collins Natural Areas Department conducted breeding bird surveys along the Poudre River from the town of La Porte south to Interstate-25 in 2009, 2010, and 2014. This effort produced a data set that provided an inventory of species, their distribution, and abundance, and that will inform this metric henceforth.

Recommended Ranges

<u>Aquatic insects</u>: A- to C
Native fish: B+ to C+
Trout: A to B
Aquatic habitat connectivity: C
Birds: A to B+

IV Application and Management

Current Condition and the 2016 State of the River

In addition to articulating the City's vision for the River, this framework establishes a mechanism to organize, monitor and report comprehensively on specific metrics of river health. The following section provides a snapshot of the current condition for each metric based on best available data and expert opinion. To fill in the data gaps regarding current conditions, the City is planning to conduct a State of the River Assessment in 2016 utilizing the RHAF as its basis.

While the RHAF draws on available data to inform the grading guidelines, the RHAF itself is not intended to provide a comprehensive assessment of current conditions. That is the purpose of the State of the River Assessment. Nevertheless, Table 34 below provides a snapshot of known or estimated current conditions to provide perspective to the RHAF's recommended ranges. In doing so, it uses the U.S. Environmental Protection Agency's following three-tiered assessment framework to describe the type of data used to create the health preview:

Level 1= remote assessment that typically relies on Geographic Information System
Level 2= rapid field-based assessment
Level 3= intensive, quantitative site assessment

The last column in Table 34, entitled 'Data Availability,' applies this three-tiered approach but adds an additional level, denoted as IE (informed estimate). IE refers to a "desktop" level of assessment by technical experts familiar with the study area. For some metrics the informed estimate is applied in conjunction with other available data that does not directly correspond to these grading guidelines. In the 2016 State of the River Assessment, a field based rapid assessment approach (Level 2) will be used to develop a more complete report of the current condition.

In 2016, the City will use the RHAF to conduct a comprehensive river health assessment that will be published with a higher level of spatial detail in a report-card-style "State of the River Assessment and Report." This report will be produced periodically, every three to five years, and will enable the City to benchmark current conditions for each river reach against the recommended ranges.

Table 34: A summary of the known or estimated current condition for each metric in each of the four river sections, alongside the respective recommended ranges. The last column provides an indication of the type of data used to describe current condition. The ranges provided reflect the range of conditions within each reach and are presented based on sample units appropriate to the data or knowledge available.

Indicator	Metric	Recommended range	Current condition by RHAF Sections				Data availability
			Canyon	Transition	Urban	Warm	
Flow regime	Peak flows	B	unk[1]	C+	C-	B	3
	Base flows[2]	B+ to C	unk	C	D+	D-	3
	Flow rate of change	B	A to B+	C to D	C to D	C	3
Sediment	Land erosion	A to B+	A to B+	A to C			IE
	Channel erosion	B	A	B to C			IE
	Transport	B to C	A to B	B to C			IE
Water quality	Temperature	A to B+	D	D	B+	B-	3
	Nutrients (TN/TP)[3]	A to B+	B+/B	A to B+	A to B+	C to F	3
	pH	A to B+	A	B+	A	A	3
	Dissolved oxygen	A to B+	B+	A	A	B	3
Floodplain connectivity	Extent	B to C+	N/A	D+	B to C+	A	1
	Saturation duration[4]	B to C+	A to B	unk	unk	unk	-
Riparian condition	Vegetation structure & complexity	B to C+	A to B	C	C	C	IE
	Habitat connectivity	B to C+	A	B to C	B to D	B to F	IE
	Contributing area	B to C+	A to B+	C	B to D	C	IE
Debris	Large wood	A- to C	C	B	C	unk	IE
	Detritus	B+	B+	B+	B+	B+	IE
River form	Planform	A to C+	A	A- to C	B to D	A- to C	IE
	Dimension	A to C+	B	A- to C	B to D	A- to C	IE
	Profile	A to B	A	B to C-	B- to D	B+ to C	IE
Channel resilience	Dynamic equilibrium	B+ to C+	B+	C	C to D+	C	IE
	Channel recovery	B+ to C+	B+	C	C to D+	C	IE
Physical structure	Coarse scale	B to C+	B	B to C	C to D	B+ to C	IE
	Fine scale	A to B-	A to B+	C	B to C	B+ to B-	IE
Aquatic & riparian wildlife	Aquatic insects	A- to C	unk	unk	B to C	C to D	3
	Native fish	B+ to C+	unk	unk	C to D	C to D	3
	Trout	A to B	unk	unk	B to C	N/A	3
	Aquatic habitat connectivity	C[5]	A to C-	C- to F	D to F	D to F	1
	Birds	A to B	unk	B to D	B to D	B	3

1. **Unk** stands for unknown, meaning the technical experts were not comfortable developing an informed estimate**. IE** stands for informed estimate. **N/A** stands for not applicable, as the RHAF explicitly is not going to evaluate the given metric for that reach.
2. Base flow current conditions were considered in light of the numeric grading guidelines ascribed to winter base flows. Summer conditions were NOT included in this assessment of current conditions.
3. Nutrients are reported as TN (total nitrogen) and TP (total phosphorus).
4. Saturation duration is a local result of both flow regime and topography. Too many unknowns contribute for the authors to comfortable provide an informed guess. This metric may be further developed during the first field application of the RHAF in 2016.
5. A C grade is recommended for aquatic habitat connectivity for all river sections below the mouth of the canyon. Higher grades already exist for the upper reaches of the river.

Relationships, Stressors, and Degrees of Influence

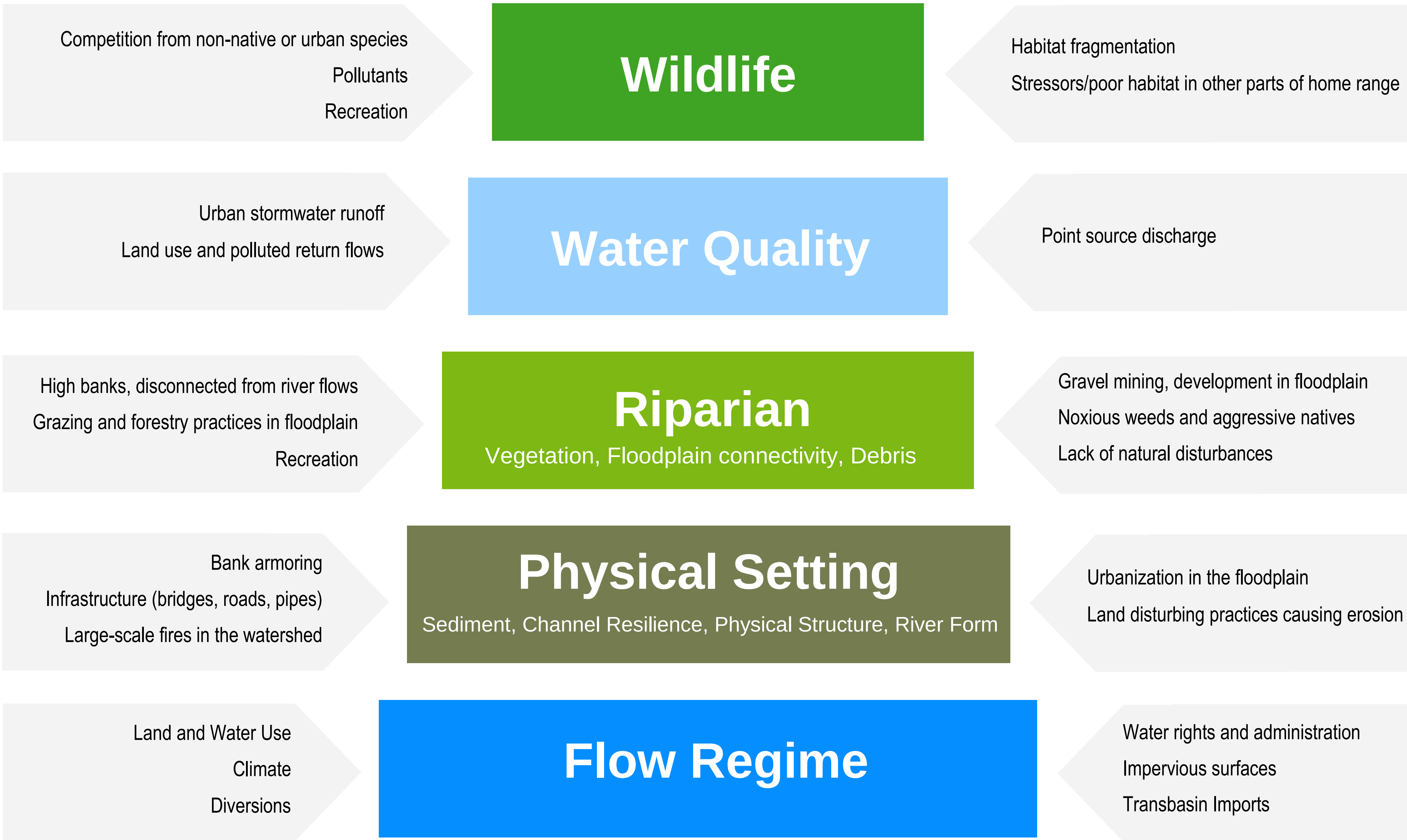
Another application of the framework will be as a decision support tool for future watershed and river management. In addition to helping illuminate complex ecological interrelationships and, the framework enables the City to better understand the varying degrees of influence that any given stressor has on overall river condition. In light of the City's limited role in the overall management of the Poudre River and specific ability to influence each stressor, it can begin to consider opportunities and challenges in its effort to work towards a resilient future Poudre River and the watershed services it provides.

The Poudre River's condition is not simply a sum of its individual parts. It is widely recognized that indicators of a river system are interdependent and interact in complex ways. However, the nature of this interaction tends to be largely directional, meaning that some indicators have further reaching effects within the ecosystem than others.

The U.S. Environmental Protection Agency developed a 'functional pyramid' to describe the relationship among river ecosystem attributes (Harmon, 2012). Figure 3 depicts a Poudre River-specific functional pyramid with system stressors indicated on the outside of the pyramid. As the pyramid indicates, flow regime is the fundamental driver of river health and affects all aspects of the ecosystem. The physical template of the river is the next most widely influential group of indicators; however, there is strong feedback between the river's physical form and its riparian zone, since vegetation protects and stabilizes the river's banks and keeps it on course. Water quality is influenced by the indicators depicted below it and is essential to sustaining aquatic and riparian wildlife.

Stressors impair the ability of the river to support life. Due to interactions between the indicators, the effects of a stressor on one component will ripple through the ecosystem, impacting all subordinate indicators and the functions they drive. For example, when active management of flows causes a reduction in the magnitude and frequency of high flows, this would be expected to cause a change in river shape through sediment buildup and other processes. Riparian and wetland dependent species are likely to decline, owing to the lack of vital moisture and flood-induced germination. Water quality would likely degrade because of contaminant concentration. Finally, fish and aquatic insect populations would likely suffer because of all of the aforementioned changes.

Figure 3: Poudre River functional pyramid (as modified from original version in EPA (2012)). Central pyramid depicts the dependence and influence of each higher level component on the lower ones. Stressors on each component are indicated in gray bars on the sides.



The Poudre River has been altered for more than a century and a half. Studies indicate the river has been on a trajectory of ecological decline which could continue in the future (City of Fort Collins, 2014). As described in Figure 4 below, extensive factors or stressors limit the condition of each river health indicator. Some of these stressors pose significant challenges for the City in achieving its vision of maintaining a healthy and resilient river owing to the varying degree of influence it has on stressors.

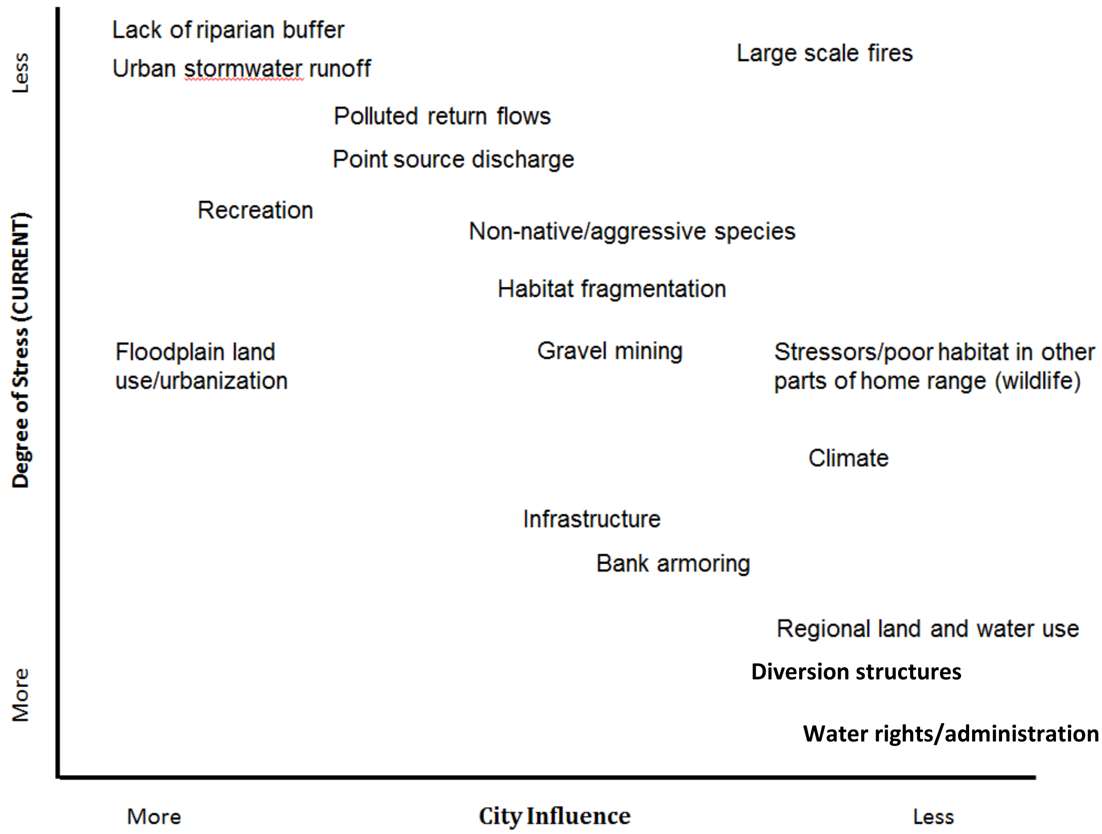


Figure 4: Diagram showing stressors and their relative impact on the whole river system as well as the City's ability to influence change (considering jurisdictional limitations, scope of stressor, and legal frameworks)

For example, reconnecting the river to its floodplain in an area owned primarily by the City is a functional improvement the City can choose to act on and likely accomplish. On the other end of the spectrum, climate is well beyond the City's control. Many of the stressors fall somewhere in the middle of this spectrum. The City does have the ability to affect change through some form of influence, collaborative partnerships, and long-term internal commitment. The Lower Poudre Monitoring Alliance is one example of collaboration between businesses and government agencies designed to monitor and make publicly available information about the water quality on the Poudre River from Fort Collins to Greeley. Positive changes will require long-term commitments from multiple stakeholders. Innovative funding strategies will be needed to overcome the declining ecological trends on the Poudre and achieve or maintain the recommended ranges. Efforts to maintain and improve river health will also need to be integrated with economic and social goals.

Management Applications

While this framework will serve as a guidance document for numerous City initiatives, the degree to which it informs a specific project or question will be varied. For some, the lens of the RHAF will provide supplemental information to the City's Sustainability Assessment Tool. For example, a project that is not focused on the river, but that overlaps geographically (e.g., transportation or utilities infrastructure) may consider the RHAF to understand potential impacts on the river and possible mitigation actions. On the other hand, a project focused on a particular aspect of river ecology might use the RHAF directly to evaluate treatment effectiveness or monitor long-term changes.

Another important application of this framework is organizing the results from existing and ongoing monitoring efforts into a common platform for communicating river condition, successes, and potential new concerns. Having a common platform and increased accessibility to information may enable City managers, staff and public alike to engage in more informed dialogue and decision-making about the Poudre River. Finally, by considering the River as an ecosystem with many interrelated parts, rather than discussing and evaluating components of the River independently, the RHAF can lead to management decisions that can have a positive effect that ripple through much of the system.

Photo by Norm Keally

Lifetime of this report

This framework represents an important tool for assessing future projects and informing dialogue around the River. To some degree, it will continue to be refined, particularly in terms of the spatial and temporal distinctions that will be refined during the field work of the 2016 State of the River Assessment.

Further, an extensive amount of Poudre River research and data collection is ongoing but not available at this time. As new data become available, the grading guidelines may be refined or enhanced. However, the recommended ranges for each metric are less likely to change for the lifetime of this document. The RHAF report will be updated in ten years and may reconsider some of the recommended ranges at that time.

V Summary

The goal of this initiative was to develop a framework to quantitatively describe the City's aspirations for a healthy and resilient Poudre River. The RHAF takes a comprehensive look at the components and thresholds necessary to have a functioning river, which in turn supports river health and resiliency. The A through F grading system and associated guidelines provide clear definitions for each metric and grade level. Thus while the terms 'healthy' and 'resilient' are acknowledged to be subjective, grade descriptions provide objective science-based criteria to describe condition classes that are based on substantial local expertise, available data, and application of ecological theory.

The recommended ranges set forth in this report aspire to maintain a sustainable ecosystem that has a low risk for functional impairment. In the RHAF, the terms 'healthy' and 'resilient' are described through recommended ranges for each metric. These work synergistically to support a more robust, functional ecosystem that is more resilient to future disturbances, stochastic events, and short-term or localized human-caused impacts. The closer any single metric gets to the C- to D+ threshold, the more at-risk it becomes. A grade of D or F indicates impairment or imminent vulnerability which may have broad implications for entire system.

	A
Resilient	**B**
	C
At risk	
Impaired/Vulnerable	**D**
	F

A number of the ranges recommended herein aspire for some degree of functional improvement from the current condition. Nonetheless, the framework recognizes that real-world challenges can limit the pace or feasibility of potential improvements. Thus, the recommended ranges accept that if some metrics remain steady or improve only slightly the system may still function well.

It is hoped that this new tool will enhance the City's interdisciplinary approach towards river management, by providing a common platform for communicating about the river that reaches across departments. The RHAF will help guide, align, and evaluate City's river-related initiatives, while also informing larger-scale regional collaborative dialog.

Photo by Norm Keally

References

City of Fort Collins, 2012. Assessments and Rehabilitation Decision-Making Framework for the Streams of Fort Collins. Prepared by Beeby, J., Kulchawik, P., and B. Bledsoe, Colorado State University, for the City of Fort Collins Stormwater Department..

City of Fort Collins. 2014. Ecological Response Model for the Cache la Poudre River through Fort Collins. Ecological Response Modeling Team.

Harman, W., R. Starr, M. Carter, K. Tweedy, M. Clemmons, K. Suggs and C. Miller. 2012. A Function-Based Framework for Stream Assessment and Restoration Projects. US Environmental Protection Agency, Office of Wetlands, Oceans, and Watersheds, Washington, DC EPA 843-K-12-006.

Beardsley, M., B. Johnson and J. Doran. In Prep. Functional Assessment of Colorado Streams (FACStream) Method. Report to be submitted to US Environmental Protection Agency and the CO Water Conservation Board. Personal communication Jan. 10, 2015 and July 7, 2015.

Appendices

Appendix A Comparison of FACstream Framework and RHAF

Table A.1 A side-by-side comparison of the FACstream variables and subvariables with the associated RHAF indicators and metrics (M. Beardsley pers. communication July 7, 2015).

FACstream version 0.7 (7/7/2015)		RHAF	
Variable	Subvariable	Indicator	Metric
Flow Regime	Peak flows	Flow Regime	Peak flows
	Base flows		Base flows
	Flow variability		Rate of change
Sediment regime	Land erosion	Sediment	Land erosion
	Channel erosion		Channel erosion
	Transport		Transport
Water quality	Temperature	Water quality	Temperature
	Organics/nutrients		Nutrients
	Inorganics/toxins		pH
	Dissolved oxygen		Dissolved oxygen
Floodplain connectivity	Extent	Floodplain connectivity	Extent
	Saturation frequency		Saturation duration
	Saturation duration		
Riparian vegetation	Riparian area vegetation	Riparian condition	Vegetation structure and complexity
	Streamside vegetation		Habitat connectivity
			Contributing area
Debris supply	Large wood	Debris	Large wood
	Detritus		Detritus
Resilience	Biotic processes	Channel resilience	Dynamic equilibrium
	Physical processes		Channel recovery
Stability/resistance	Lateral stability		
	Vertical stability		
	Enlargement		
Morphology	Planform	River form	Planform
	Dimension		Dimension
	Profile		Profile
Physical structure	Coarse structure	Physical structure	Coarse structure

	Fine structure		Fine structure
Biotic structure	Aquatic vegetation	Aquatic and riparian wildlife	Aquatic insects
	Macroinvertebrates		Native fish
	Fish and amphibians		Trout
	Other animals		Aquatic habitat connectivity
			Birds

Appendix B Further Explanation of Guiding Concepts

Several fundamental principles or 'guiding concepts' of modern river systems underlie the recommended ranges embodied in the RHAF. These principles are essential to understanding and maintaining the resilience of the River and community in the face of major disturbances such as floods, fires and drought. The following section provides further description on the six guiding concepts presented initially in the main RHAF report.

Variability in this case refers primarily to daily, seasonal and inter-annual variability in the flows. The Poudre River ecosystem evolved with, and therefore depends on, flow variability and particularly the much higher flows that occur each May and June from spring snow melt. Another type of natural flow variability is the difference across wet, average and dry years in the spring peak flows. Outside of the peak flows, the natural system generally develops a more constant daily base flow level, but seasonal thunderstorms cause significant flood flows as occurred in 2013. These types of flow variability are natural and the native ecosystem is not only resilient to it but also depends on it. It is crucial to understand and incorporate these expected patterns of flow variability into plans aimed at maintaining system resilience.

Disturbance refers to natural and characteristic regime of ecological disruption that occurs within the system. Disturbance supports many aspects of the river system including cleansing of riverbed habitats, sediment transport, nutrient cycling, and cottonwood tree and willow regeneration. Examples of characteristic disturbances that support a healthy river include mild wildfires and floods and the resulting changes they cause in the river landscape. In planning for the resilience of communities that live around rivers in this region, planning for the natural and expected occurrences of future disturbances is imperative.

Biodiversity refers to variety of life and habitat types found within the system. Biodiversity is a term that can be applied at many scales. There is biodiversity across the watershed and there is also biodiversity within a small wetland. Biodiversity supports the system's ability to recover after disturbance and continue providing ecological services to society. Increased biodiversity is directly correlated with increased ecosystem resilience.

The Poudre River has been affected by anthropogenic activities for more than 150 years. It is difficult to overstate the impacts of diversions, floodplain development, infrastructure, non-native species, and pollutants on the system. This modern context changes many facets of the native ecosystem which is and explains the fourth guiding concept of **novel ecosystem**. Given the many changes some aspects of the system will not ever return to a more native condition. Others are fundamentally impaired and overall ecosystem condition will always be limited unless those issues are improved upon. Therefore, in determining the spectrum for assessment and establishment of recommended ranges, this concept directs us to consider the best obtainable condition for some variables in the context of a novel ecosystem.

A fourth guiding concept central to the state of the river is the resilience and **condition of the contributing watershed** that feeds into the focal river segment. The contributing watershed is about 1600 $miles^2$ and has a pivotal effect on the river's condition as the City experiences it. Managing it is primarily beyond the City's scope and jurisdiction; however, the condition of the river as the City inherits it from the upper watershed fundamentally determines aspects of the river's condition and sets limits as to how resilient and healthy a system the City can aspire to maintain. It also creates other challenges for the City which seeks to meet its own diverse objectives in support of its communities, such as maintenance roads and utilities infrastructure, water supply and maintenance of discharge permits, and conveyance of storm water and effluent.

The City, in working towards its objectives and river health recommended ranges, will not generally measure or monitor the watershed condition itself, but instead it would evaluate the condition of the aquatic and riparian ecosystem as it enters the City's prevue. In this way, antecedent conditions would provide a baseline description of water quality, flow, habitat and other factors serve, while also serving as a proxy for extensive and costly studies and monitoring of the upper watershed. Considering the inherited condition will help the City identify emerging issues that it may be challenged with in the future. The City will continue to engage and support external efforts that benefit the condition of watershed. One such example is the City's participation in recovery efforts after the High Park Fire and in the subsequent establishment of the Coalition for the Poudre River Watershed.

Finally, the sixth guiding concept aims to recognize that the system and its management falls across a complex jurisdictional and legal framework and therefore **collaboration and partnerships** are necessary for progress. Because this project takes a holistic and functional systematic approach towards understanding influences on the River's health, it addresses the pressures imposed on the River by the urban, commercial, and agricultural landscape within the City, but it also considers factors largely beyond the City's control. Some examples include; groundwater characteristics, the condition of the contributing watershed, and nutrients in return flows from agricultural lands. Table B.1. provides a list of organizations or interest based groups working on the Poudre River.

Table B.1 Stakeholders and collaborators on the Poudre River

General category	Specific stakeholders and partners
Internal	Collaboration across City departments
Recreation based interest groups	Trout Unlimited, St.Pete's, Rocky Mountain Flycasters, kayakers, rafting/boating companies
Academic, research	Colorado State University, University of Colorado, Front Range Community College, other data collaborators
Fort Collins business and organizations	Downtown Business Association, Downtown Development authority, breweries
Ditch companies/water users	Northern Water Conservancy District, Thornton, Cache la Poudre Water Users Association, other ditch companies
Public agencies	U.S. Army Corps of Engineers, U.S. Environmental Protection Agency, Colorado Parks and Wildlife, Colorado Department of Public Health and Environment, Water Commissioner-state, U.S. Forest Service, U.S. Bureau of Reclamation
Non-profits working on the Poudre	Coalition for the Poudre River Watershed, Poudre Heritage Alliance, Colorado Water Institute (Poudre Runs Through It), Poudre River Trust, Colorado Water Trust, The Nature Conservancy, Save the Poudre
Poudre communities	LaPorte, Timnath, Windsor, Greeley
Water utilities and collaborators	Greeley, Tri-Districts, CSU, Boxelder Sanitation District, South Fort Collins Sanitation District, Town of Windsor, Carestream Health (formerly Kodak Colorado Division), City of Greeley, Leprino Foods, Inc.

Appendix C Reasoning and data sources behind the development of grading guidelines

As described in Section III of the report, the RHAF is adapted from the FACstream methodology. Appendix C provides the rationale for the grading guidelines, indicators and metrics that changed substantially from the FACstream. Additionally a brief description is provided for some of the metrics to explain the reasoning or data behind the current condition reported in Table 34 of the main report. The indicators of Sediment and Debris are not included in the following descriptions because these grading guidelines were adapted directly from the FACStream, with only minor modification to remove situations and stressors that do not fit in the Poudre River context.

Indicator 1: Flow Regime

By design, the Flow Regime metrics and grading guidelines were based upon the flow regime requirement to support the recommended ranges of other metrics within the framework. Because few empirical relationships were available between other RHAF metrics and flows, the following numeric criteria for flow regime were based upon the Ecological Response Model (ERM)[1] developed in a partnership led by the City of Fort Collins Natural Areas department.

Metric: Peak Flows

The grading guidelines for peak flows are based upon FACStream framework and refined with site specific information on the ecological functions. Numeric criteria for Peak Flows are based upon the Channel Structure indicator of the ERM which in-turn is based upon the shear stress necessary to mobilize the channel substrate and to flush fine sediment from the river bed. There are three aspects of Peak Flows:

- **magnitude**: the volumetric discharge of the peak flow (reported daily average discharge in cubic feet per second (cfs))[2]
- **frequency**: how often peak flows of a desired magnitude occur (reported as a return interval in years)
- **duration**: the length of time discharge is above a desired magnitude (reported as number of day)

To relate flows to shear stress, the ERM team modeled 53 different river flows ranging from 50 cfs up to 9,000 cfs using the HEC-RAS 1-D hydraulic model to develop piecewise, at-a-station hydraulic geometry relationships for hydraulic radius, friction slope, shear stress, and dimensionless shear stress as functions of discharge for representative cross sections in each reach. Dimensional shear stress from HEC-RAS was then converted to dimensionless shear stress (τ^*) which is referenced to the median grain size (d_{50}) of the river bed (see Table C. 1). The values for the magnitude, frequency, and duration of desired peak flows are based upon flushing and mobility conditions suggested by available literature (Wilcock *et al.*, 1996; Milhous, 2009; Milhous, 2012). More specifically, the target frequency for bed mobility is 1 in 3 years and flushing is 2 in 3 years. The required duration of 3 days above desired magnitudes is the middle of the suggested range of 1 to 5 days.

Table C. 1 - Discharge (cfs) corresponding to three thresholds of dimensionless shear stress at the three ERM study locations (reprinted from ERM, 2012)

Location	$\tau_* = 0.021$	$\tau_* = 0.03$	$\tau_* = 0.035$	$\tau_* = 0.06$
Reach 3a: Taft to Shields	1,750	2,700	3,300	6,900
Reach 3b: Shields to College	1,400	2,500	3,200	8,000
Reach 7: Boxelder Gage to I-25	900	1,550	2,100	9,200

[1] The ERM full report, appendices, and flow data available online http://www.fcgov.com/naturalareas/eco-response.php

[2] Daily average discharge is the most commonly available discharge data type from the USGS and other sources, thus all criteria will be based upon daily average discharge

Metric: Base Flows:

Numeric criteria for Base Flows are based upon the low flow needs of juvenile (young-of-year) brown trout. The ERM report suggests that numbers of young brown trout are higher when Poudre River flows average 35 cfs or higher in the period between November and March, reflecting good conditions for incubation of embryos (i.e., adequate flow of water through sediment-free gravel riffles where eggs are deposited), and a subsequent relatively higher survival through to the following autumn.

Metric: Rate of Change:

The Rate of Change metric was added to the original FACStream framework because rapid rates of change within short time periods (hours) are a well-recognized concern on the Poudre through Fort Collins. The grading guidelines for this metric are based on the general understanding of impacts of rapid changes to aquatic species (Cushman, 1985; Bunn and Arthington, 2002). However, no data were available specifically relating short term changes to stress and survival of aquatic life.

Analysis of Current Condition

Canyon: the flow regime analysis is based on USGS[3] and Colorado Division of Water Resources[4] Canyon Mouth gage data. This gage is located below multiple major diversions from the Canyon section itself, but the only gage in the Canyon section is the City of Fort Collins gage on the Hewlett Gulch Bridge[5] which has only been in operation since 2014.

> *Peak Flows* – Reported as Unknown. No analysis was conducted for the geomorphic relationship to peak flows in the ERM for this section.
>
> *Winter Base Flows (Nov-Feb)* – Reported as Unknown. Based on Canyon Mouth gage which is below multiple major diversions from the Canyon Section itself, thus gage base flow values are likely underestimates of actual daily average base flows in the Canyon.
>
> *Rate of Change* – Reported as A to B+ using "informed estimate" because the only unnatural effects would be reservoir delivery.

Transition: Flow regime analysis based on Canyon Mouth gage which is at upstream end this Transition section. Lower end of Transition section is located in ERM Reach 3a.

> *Peak Flows* – The source of data was the daily average flow from the Canyon Mouth gage (WY 1976-2014). A return interval (RI) of 4.9 years for 3300 cfs flow and RI of 2.1 years for 2700 cfs flow. Hence the current condition of this section is a C+.
>
> *Winter Base Flows (Nov-Feb)* – According to Canyon Mouth gage data the winter average is above 35cfs 51.3% of years and above 20cfs 97.4% of years. 4 in 5 winters have at least one

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[3] for data 1881-2007 http://waterdata.usgs.gov/co/nwis/inventory/?site_no=06752000
[4] for data 2007-present
http://www.dwr.state.co.us/SurfaceWater/data/graphdata.aspx?ID=CLAFTCCO&MTYPE=DISCHRG
[5] currently available by navigating to the gage location on
http://gisweb.fcgov.com/Html5Viewer/Index.html?viewer=flood%20warning&gage=stream

single daily average flow less than 20 cfs and thus fail the winter base flow B grade. Hence the current condition is reported as a C.

Rate of Change – Reported as C to D using "informed estimate" because high volume diversions and known dry ups around Watson Lake and below Larimer and Weld Ditch.

Urban: The flow regime analysis is based on data from the USGS Gage at Lincoln Ave[6]. The upper end of Urban section is in ERM Reach 3a and contains ERM Reach 3b as well, thus data was sourced from the ERM results for these reaches.

Peak Flows –The data source was the daily average at Lincoln gage (WY 1976-2014). The return interval (RI) for 3300 cfs flow is 7.8 years and RI of 4.3 years for 2700 cfs flow. Hence the current condition of this section is on the lower end of C.

Winter Base Flows (Nov-Feb) – The winter average at the Lincoln gage is above 35cfs in 36% of the years and above 20cfs 39% of the years. All winters in 39 year dataset had daily average minimum flow below 20 cfs. Hence the current condition of this section is a D+.

Rate of Change – Reported as C to D using "informed estimate" because several diversions exist in this reach, but divert lower volumes of water than those upstream. There is potentially more groundwater from the urban landscape and reclaimed water return flows moderate shifts.

Warm: The flow regime analysis is based on the USGS Boxelder Gage[7] which is located at the upstream end of this Section. ERM Reach 7 is contained in this Section.

Peak Flows – The data source was the daily average flow from Boxelder gage (WY 1976-2014[8]). The return interval for 2100 cfs flow (RI) is 2.8 years and 2.4 years for 1550 cfs flow. Hence the current condition is a B.

Winter Base Flows (Nov-Feb) – The winter average at the Boxelder gage is above 35 cfs 17.9% of the years and above 20cfs 21% of the years. Only 1 of 39 winters in dataset had daily average minimum flow above 20 cfs. Hence the current condition is a D-.

Rate of change – Reported as C using "informed estimate" because there are relatively fewer diversions in this section and more groundwater and reclaimed water return flows moderate shifts.

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[6] http://waterdata.usgs.gov/co/nwis/uv/?site_no=06752260&agency_cd=USGS

[7] http://waterdata.usgs.gov/nwis/uv/?site_no=06752280&agency_cd=USGS

[8] 1976-1979 daily average flow pulled from Northern Colorado Water Conservancy District daily point flow model and added to available gage data

Indicator 3: Water Quality

Water quality can be defined by its physical, chemical, biological, and aesthetic attributes, which are not only important for the protection of public health, but also the environment. The quality of water is essential to support a healthy and resilient river ecosystem capable of sustaining fish and insect populations, aquatic vegetation and riparian forests, and terrestrial wildlife. Monitoring is an important tool in evaluating the water quality, and certain metrics can be measured to determine the presence or absence of contaminants in water.

The Colorado Department of Public Health and Environment Water Quality/Control Division (CDPHE/WQCD) have established a regulatory framework for classifying and assigning water quality standards to state surface waters. The regulations provide numeric and narrative criteria, adopted by the Water Quality Control Commission, using the best available knowledge to maintain and improve water quality for beneficial uses including public water supplies, domestic, agricultural, industrial and recreational uses, and the protection of terrestrial and aquatic life (CDPHE, 2013).

The Poudre River, within the geographic scope of this project, is classified into three stream segments in accordance with the CDPHE Regulation No. 38 (CDPHE, 2014). The Canyon stream section, downstream of the Munroe Diversion, and the Transition stream section are classified as stream segment 10, while the Urban and Warm stream sections are classified as stream segments 11 and 12, respectively. The Canyon Section upstream of the Munroe Diversion is classified into three stream segments (1, 2a, and 2b) with segment 1 beginning at the headwaters in Rocky Mountain National Park. Stream Segment 10 is classified as “coldwater aquatic life”, while the Stream Segments 11 and 12 are classified as “warmwater aquatic life” (Figure C.1).

The classification of cold and warm water segments was established based on aquatic communities’ tolerance to changes in water temperature and, therefore, specified stream segments are capable of supporting and protecting species that are tolerant of the segments temperature regime. In addition, the classified segments have defined numeric standards for physical and biological water quality parameters, inorganics, metals, and temperature (Table C.2). In June 2012, the Colorado Water Quality Control Commission adopted numerical Regulation #31, which provides for scientifically-based numerical nutrient values designed to protect the designated uses of waters in the State of Colorado, including the protection of aquatic life, recreation, and municipal water supplies. The initial phase of implementation from 2012 to 2017 applies interim numerical values for phosphorus, nitrogen, and chlorophyll-a (Table C.3).

Currently, the City of Fort Collins Utilities manages two collaborative water quality monitoring programs on the Poudre River. The Source Water Monitoring Program monitors water quality in the Upper Cache la Poudre Watershed from Cameron Pass to the canyon mouth. The program was designed to support the protection of the City’s drinking water supplies by determining impacts of land use and human activity on our source water quality (*http://www.fcgov.com/utilities/what-we-do/water/water-quality/source-water-monitoring*). The Lower Poudre Water Quality Monitoring Program has a network of monitoring locations in the Lower Watershed (Fort Collins to Greeley). This program monitors treated water that is returned to the Poudre River above and below water reclamation facilities. This program is designed to track regulatory changes, water quality trends and progress in stormwater quality management (http://www.fcgov.com/utilities/what-we-do/water/water-quality/lower-poudre-monitoring).

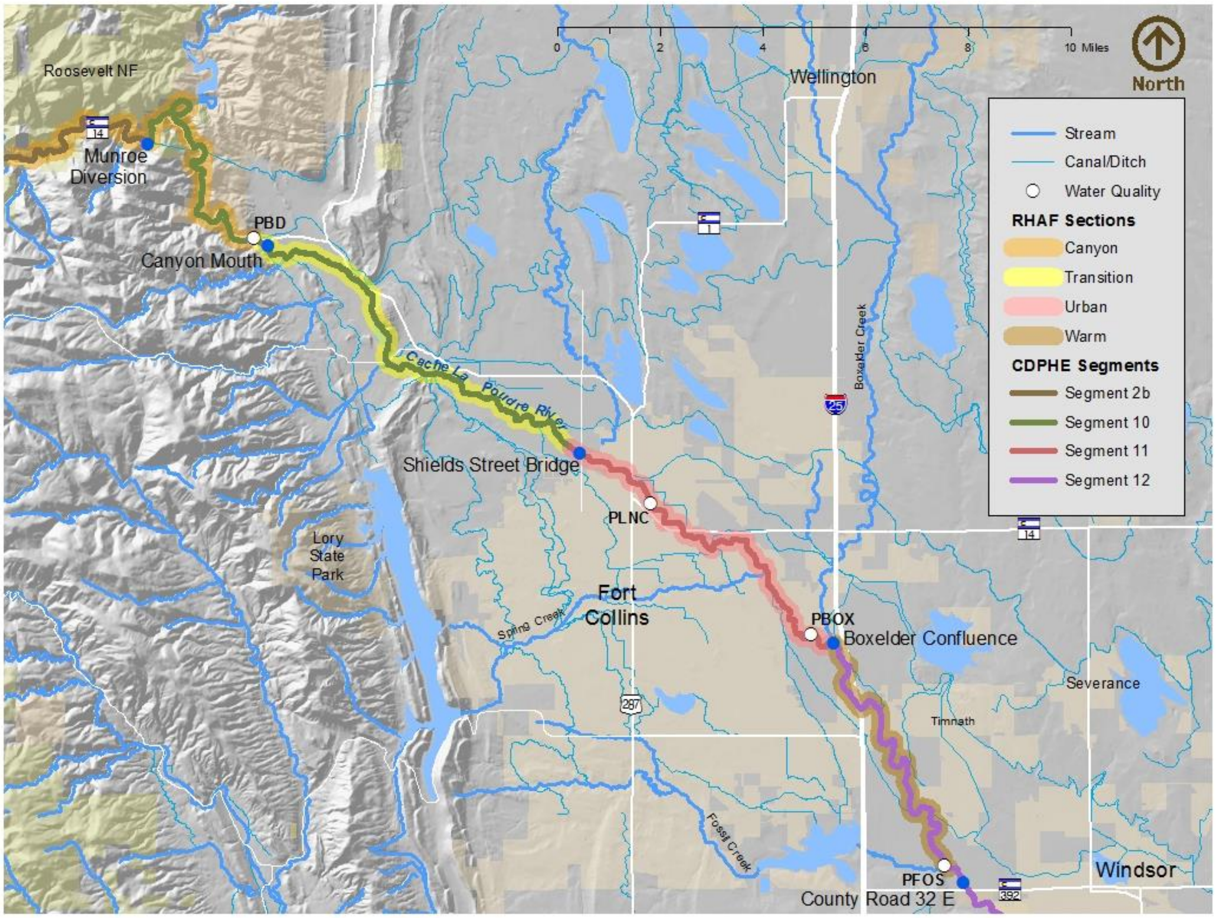

Figure C.1 – The River Health Assessment Framework study area including defined river sections, CDPHE classification segments, and water quality monitoring locations.

Table C.2 – Colorado Stream Classifications and water quality standards for the Cache la Poudre River.

Stream Segment and Description	Classification	NUMERIC STANDARDS						Temperature Standard, Celsius		
		Physical and Biological	Inorganic mg/L		Metals ug/L			Month	MWAT[2]	DM[3]
10 Mainstem of the Cache La Poudre River from the Monroe Gravity Canal/North Poudre Supply Canal diversion to Shields Street in Ft. Collins, Colorado.	Aq Life Cold 2 Recreation E Water Supply Agriculture	D.O.=6.0 mg/l D.O.(sp)=7.0 mg/l pH=6.5-9.0 E.Coli=126/100ml	NH3(ac/ch)=TVS[1] Cl2(ac)=0.019 Cl2(ch)=0.011 CN=0.005	S=0.002 B=0.75 NO2=0.05 NO3=10 Cl=250 SO4=WS	As(ac)=340 As(ch)=0.02(Trec) Cd(ac)=TVS(tr) Cd(ch)=TVS CrIII(ac)=50(Trec) CrVI(ac/ch)=TVS Cu(ac/ch)=TVS	Fe(ch)=WS(dis) Fe(ch)=1000(Trec) Pb(ac/ch)=TVS Mn(ac/ch)=TVS Mn(ch)=WS(dis) Hg(ch)=0.01(Tot)	Ni(ac/ch)=TVS Se(ac/ch)=TVS Ag(ac)=TVS Ag(ch)=TVS(tr) Zn(ac/ch)=TVS	Apr - Oct. Nov - March	18.2 9.0	23.8 13.0
11 Mainstem of the Cache La Poudre River from Shields Street in Ft. Collins to a point immediately above the confluence with Boxelder Creek.	Aq Life Warm 2 Recreation E Agriculture	D.O.=5.0 mg/l pH=6.5-9.0 E.Coli=126/100ml	NH3(ac/ch)=TVS[1] Cl2(ac)=0.019 Cl2(ch)=0.011 CN=0.005	S=0.002 B=0.75 NO2=2.7 NO3=100	As(ac)=340 As(ch)=7.6(Trec) Cd(ac/ch)=TVS CrIII(ac/ch)=TVS CrVI(ac/ch)=TVS Cu(ac/ch)=TVS	Fe(ch)=1000(Trec) Pb(ac/ch)=TVS Mn(ac/ch)=TVS Hg(ch)=0.01(Tot) Ni(ac/ch)=TVS	Se(ac/ch)=TVS Ag(ac/ch)=TVS Zn(ac/ch)=TVS	Mar – Nov Dec – Feb	24.2 12.1	29.0 14.5
12 Mainstem of the Cache La Poudre River from a point immediately above the confluence with Boxelder Creek to the confluence with the South Platte River.										

[1] Table Value Standard
[2] Maximum Weekly Average Temperature
[3] Daily Maximum

Table C.3 – Colorado Stream Classifications and interim nutrient standards on the Cache la Poudre River.

<table>
<tr><th rowspan="2">Stream Segment and Description</th><th rowspan="2">Classification</th><th colspan="3">INTERIM NUTRIENTS STANDARDS</th></tr>
<tr><th>Interim Total Phosphorus Values</th><th>Interim Nitrogen Values (Effective May 31, 2017)</th><th>Interim Chlorophyll a Values</th></tr>
<tr><td>10
Mainstem of the Cache La Poudre River from the Monroe Gravity Canal/North Poudre Supply Canal diversion to Shields Street in Ft. Collins, Colorado.</td><td>Rivers and Streams – cold</td><td>110 ug/L [1]</td><td>1,250 ug/L [2]</td><td>150 mg/m2 [3]</td></tr>
<tr><td>11
Mainstem of the Cache La Poudre River from Shields Street in Ft. Collins to a point immediately above the confluence with Boxelder Creek.</td><td rowspan="2">Rivers and Streams - warm</td><td rowspan="2">170 ug/L [1]</td><td rowspan="2">2,010 ug/L [2]</td><td rowspan="2">150 mg/m2 [3]</td></tr>
<tr><td>12
Mainstem of the Cache La Poudre River from a point immediately above the confluence with Boxelder Creek to the confluence with the South Platte River.</td></tr>
</table>

[1] annual median Total Phosphorus (ug/L), allowable exceedance frequency 1-in-5 years.
[2] annual median Total Nitrogen (ug/L), allowable exceedance frequency 1-in-5 years.
[3] summer (July 1-September 30) maximum attached algae, not to exceed.

Grading Guideline Development

Four metrics were selected to inform the Water Quality indicator in the RHAF: temperature, nutrients, pH, and dissolved oxygen. The grading guidelines were developed using historical data collected by the City of Fort Collins Utilities' water quality monitoring programs and CDPHE water quality standards (Table 1). Two monitoring locations were identified as reference sites for the "cold" and "warm" water stream segments. Water quality from the Source Water Monitoring Program's lowest elevation monitoring site (PBD - Poudre at Bellvue Diversion) located near the canyon mouth represents cold water conditions supported by the upper watershed. The Lower Poudre Water Monitoring Program's highest elevation monitoring site (PLNC – Poudre at Lincoln Street Bridge) represents warm water conditions influenced by the lower watershed (Figure C.1).

Statistical and data analysis were performed on these two monitoring sites using box-and-whisker plots to assess and compare data distributions over the recent period of record defined as 2009 to 2013. A 5-year period of record was selected because this amount of time is generally accepted as adequate to evaluate trends and capture annual and seasonal variability. The data were divided into parts using percentiles to categorize grading guidelines (A-F). In general, the n^{th} percentile has n% of the observations below it, and (100-n)% of observations above it. The 50^{th} percentile, for example, represents the median of the data, in which half the observations fall above and half fall below. The distribution of historical data (2009-2013) embodies the "A" through "C" grades. In general, "A" and "B" grades represent acceptable water quality conditions with minimal effects from stressors and requires little to no management to sustain the current condition.

Numeric water quality regulatory standards were incorporated at the "C" grade and lower (D and F). As water quality metrics approach the regulated water quality standard there is a higher risk of exceeding the standard and management may be required to avoid exceedance. At the "C" grade the water quality standard has not yet been exceeded. If the water quality standard has been exceeded then the indicator receives a "D" grade, and if the standard is consistently exceeded an "F" grade. In most cases, stream segments that exceed the water quality standard are listed on Colorado's Section 303(d) List and Monitoring and Evaluation (M&E) List. Colorado's Section 303(d) List and Monitoring and Evaluation (M&E) List establishes Colorado's list of impaired waters and list of waters suspect of water quality problems Colorado's Section 303(d) List of Impaired Waters and Monitoring and Evaluation List, 2012). When water quality standard exceedances are suspected, but uncertainty exists regarding one or more factors (such as the representative nature of data used in the evaluation), a water body or segment is placed on the M&E List.

Table C.4 lists annual and seasonal numerical values corresponding to the grading guidelines for each water quality metric for both cold and warm water segments.

Table C.4 – Water quality table values for the River Health Assessment Framework.

Metric	Season	Segment	Water Quality Condition A	B	C	D	F
TEMP (deg C)	Apr-Oct	Cold	<11.6	11.6-15.1	15.1-23.8	see CDPHE water quality standard	
	Mar-Nov	Warm	<11.8	11.8-14.8	14.8-29.0		
	Dec-Feb		0.2-1.0	1.0-2.3	2.3-14.5		
TPHOS (ug/l)	Annual	Cold	<35	35-110	>=110	>110	
		Warm	<55	55-170	>=170	>170	
	Winter	Cold	<58	58-110	>=110	see CDPHE water quality standard	
		Warm		58-170	>=170		
	Spring	Cold	<47	47-110	>=110		
		Warm	<65	65-170	>=170		
	Summer	Cold	<37	37-110	>=110		
		Warm	<25	25-170	>=170		
	Fall	Cold	<22	22-110	>=110		
		Warm	<53	53-170	>=170		
TN (ug/l)	Annual	Cold	<608	608-1,250	>=1,250	>1,250	
		Warm	<772	722-2,010	>=2,010	>2,010	
	Winter	Cold	<890	890-1,250	>=1,250	see CDPHE water quality standard	
		Warm		890-2,010	>=2,010		
	Spring	Cold	<614	614-1,250	>=1,250		
		Warm	<615	615-2,010	>=2,010		
	Summer	Cold	<650	650-1,250	>=1,250		
		Warm	<742	742-2,010	>=2,010		
	Fall	Cold	<557	557-1,250	>=1,250		
		Warm	<655	655-2,010	>=2,010		
pH	Annual	Cold	7.18-8.14	6.70-8.62	6.5-9.0	<6.5 or >9.0	
		Warm					
	Winter	Cold	7.44-7.72	7.05-8.11			
		Warm					
	Spring	Cold	7.19-8.23	6.67-8.75			
		Warm					
	Summer	Cold	7.02-7.92	6.57-8.37			
		Warm					
	Fall	Cold	7.5-8.12	7.19-8.43			
		Warm					
DO	Annual	Cold	>9.97	8.83-9.97	6.0-8.83	<6.0	<3.0
		Warm			5.0-8.83	<5.0	
	Winter	Cold	>10.33	9.34-10.33	6.0-9.34	<6.0	
		Warm			5.0-9.34	<5.0	
	Spring	Cold	>9.66	8.72-9.66	7.0-8.72	<7.0	
		Warm			5.0-8.72	<5.0	
	Summer	Cold	>9.11	8.34-9.11	6.0-8.34	<6.0	
		Warm			5.0-8.34	<5.0	
	Fall	Cold	>10.94	10.06-10.94	7.0-10.06	<7.0	
		Warm			5.0-10.06	<5.0	

Analysis of Current Condition

Current conditions were assessed using 2014 data from four water quality monitoring sites located throughout the study area (Figure C.1). Data from each water quality monitoring site were used to assess the current condition of the respective river section where the monitoring site is located. For example, data from the Poudre at Bellvue Diversion (PBD) monitoring site was used to assess conditions of the Canyon River Section. The one exception was the site located on the Poudre at the Lincoln Street Bridge (PLNC). Data from this site were used to assess the condition of both the Transition and Urban River Section because limited data are currently available for the Transition section.

Indicator 4: Floodplain Connectivity

Grading Guideline Development

Floodplain connectivity metrics include Extent and Saturation Duration. Saturation frequency is another subvariable in the FACstream but was omitted from the RHAF because the metric of peak flows incorporates the frequency of high flows. The grading guidelines for Saturation Duration remain largely unchanged from the FACstream rapid assessment language and may be further developed during the field testing phase for the State of the River assessment in 2016. Current Condition for Saturation Duration was reported as unknown in the RHAF as a site by site evaluation is needed.

Analysis of Current Condition

Current condition was analyzed by considering the historical gage data (approximately the past 50 years) as well as today's flows. A 5-year flow value of 3486 cfs was established using the historic Lincoln gage data (water years 1980- 2005) and calculated using methods described in USGS bulletin 17b (U.S. Geological Survey, 1983). Because more flows are being diverted today than over the past 40 years, a 5 year flow value of 3018 cfs was calculated using a hydrologic model of the Current Operations (Army Corps of Engineers, 2015). Riparian processes and functions occur over longer time periods, so results of both of these values (historic and current) were considered in developing the current condition grade ranges.

To determine extent, or widths of floodplain influence from the 5 year flow the following process was used in GIS;

- HEC-RAS model was run for both values (3486 and 3018 cfs).
- The width of the specified flow (excluding the main channel width) was extracted from the model results.
- Width of the flow area for each cross section was converted to meters and a weighted average by distance along the river was calculated to provide the weighted average width for each river section.

Table C.5 Width (m) of the 5 year floodplain for historic and current flow regimes. Lengths represent both sides of the river without the channel width.

River Section	River Mile	Historic (3486 cfs)	Current Operations (3018 cs)
Transition	1.1	0.0	0.0
	2.0	0.0	0.0
	3.2	1.2	0.7
	4.1	0.4	0.4
	5.1	35.9	16.7
	6.1	4.0	3.4
	7.4	16.6	11.4
	8.0	10.8	7.4
	9.1	132.3	116.0
	10.1	59.5	36.3
	11.0	3.3	2.8
	12.0	91.3	85.9
	13.0	297.2	274.2
	13.4	13.3	12.7
Transition - weighted average		49.2	41.9
Urban	14.1	4.9	3.7
	15.0	37.8	30.6
	16.1	44.8	0.3
	17.1	108.6	91.8
	18.0	9.8	8.5
	19.0	9.9	7.9
	20.2	190.9	184.3
	21.2	229.4	192.4
Urban - weighted average		86.4	70.5
Warm	22.1	214.5	160.0
	23.0	36.1	26.3
	24.0	124.5	64.2
	25.1	58.8	49.1
	27.0	272.2	250.2
	28.1	124.6	93.0
	28.7	318.1	233.2
Warm - weighted average		169.1	134.5

Indicator 5: Riparian Condition

Evaluation of riparian habitat condition requires a detailed assessment of terrestrial habitats which is beyond the focus of the FACStream, the assessment method upon which the RHAF is structured. In Clean Water Act application of riverine habitats, FACStream is intended to work in conjunction with the Functional Assessment of Colorado Wetlands (FACWet) method (Johnson et al. 2010). The FACWet is structured in a fashion very similar to FACStream, in that is includes Indicators of wetland health (“variables”) and metrics which describe those indicators (“subvariables”).

The FACWet was streamlined and customized to meet the aims of the RHAF, first by removing Indicators whose evaluation would be redundant with Indicators assessed in other portions of the RHAF and second by tailoring grading guidelines to reflect the particular ecological setting of the Poudre River and to parallel City of Fort Collins floodplain management goals. As adapted from the FACwet, three metrics were developed to describe riparian condition: Vegetation Structure and Complexity, Contributing Area, and Habitat Connectivity.

Metric: Vegetation Structure and Complexity

The City is primarily concerned with six aspects of Vegetation Structure and Complexity including; structural diversity, the presence or abundance of noxious weeds and exotic species, aggressive native species (such as cattails), overall species composition, habitat patchiness and interspersion and the regeneration of woody species, particularly cottonwoods. These habitat characteristics will be evaluated using sub-metrics that generally follow procedures found in the Colorado Natural Heritage Program’s Ecological Integrity Assessment (Lemly and Gilligan 2013) (see Tables C.5-C.). Sub-metric scores will be combined into a weighted average using the following draft values[9] (Table C.12). While the submetrics may be further refined following a field testing phase prior to the 2016 field assessment. The following tables are included to show the general outline and approach for evaluating Vegetation Structure and Complexity.

[9] Weights may be refined following field trials.

Tables C.6a and b: Structural Diversity

Stratum	Reference Coverage	Existing Coverage	Absolute Value of Difference
Tree			
Shrub			
Herb			
Sum of Difference			

Grade	Grade Range	Grading Criteria
A	90	<10% cumulative alteration
B	80	10 – 33% cumulative alteration
C	70	33 – 66% cumulative alteration
D	60	66 – 100% cumulative alteration
F	<60	>100% alteration*

* Cumulative coverage commonly is greater than 100%, therefore 100% cumulative alteration does not suggest that no vegetation is present.

Table C.7: Exotic Species Coverage

Grade	Grade Range	Grading criteria
A	90	Coverage of native species >75%
B	80	Coverage of native species 75 – 50%
C	70	Coverage of native species >50 – 25%
D	60	Coverage of native species >25 – 10%
F	<60	Coverage of native species >10%*, or vegetation absent or row crops

*% of existing vegetation.

Table C.8: Aggressive Natives

Grade	***Description***
A	Aggressive natives present, but sporadic (<10% absolute cover of cattails or <5% absolute cover of reed canarygrass or giant reed).
B	Aggressive natives common (10-25% absolute cover of cattails or 5-10% absolute cover of reed canarygrass or giant reed).
C	Aggressive natives abundant (>25-50% absolute cover of cattails or 10-25% absolute cover of reed canarygrass or giant reed).
D	Aggressive natives dominant (>50% absolute cover of cattails or >25% absolute cover of reed canary grass or giant reed grass).
F	Vegetation absent or row crops

Table C.9: Species Composition

Grade	*Mean Coefficient of Conservation Scores*
A	5
B	4
C	3
D	2
F	1

Table C.10: Patchiness and habitat interspersion

Grade	***Description***
A	High degree of horizontal interspersion: AA characterized by a very complex array of nested or interspersed zones with no single dominant zone.
B	Moderate degree of horizontal interspersion: AA characterized by a moderate array of nested or interspersed zones with no single dominant zone.
C	Low degree of horizontal interspersion: AA characterized by a simple array of nested or interspersed zones. One zone may dominate others.
D	No horizontal interspersion: AA characterized by one dominant zone.
F	Vegetation absent or row crops

Table C.11: Native Woody Species Regeneration

Grade	***Description***
N/A	Woody species are naturally uncommon or absent.
A	All age classes of desirable (native) woody riparian species present.
B	Age classes restricted to mature individuals and young sprouts. Middle age groups absent.
C	Stand comprised of mainly mature species OR mainly evenly aged young sprouts that choke out other vegetation.
D	Woody species predominantly consist of decadent or dying individuals OR AA has >5% canopy cover of Russian Olive and/or Salt Cedar.
F	Woody canopy artificially removed

Table C.12: The score for the six sub-metrics to be used in the RHAF Vegetation Structure and Complexity metric are rolled into a single score using the following weights as adapted from the Ecological Integrity Assessment:

Sub-metric	Weight
Structural diversity	0.30
Exotic species	0.15
Aggressive natives	0.15
Species composition	0.15
Patchiness and habitat interspersion	0.15
Native woody vegetation regeneration	0.10

Metric: Contributing Area
The Contributing Area metric was adapted directly from the FACWet, with minor modification to remove situations and stressors that do not fit in the Poudre River context.

Metric: Habitat Connectivity
Habitat Connectivity is graded by evaluating two aspects of the riparian corridor, the width of functional riparian habitat and the existence of human-created barriers that interfere with the movement of animals and the dispersal of seeds amongst habitats. Riparian habitat width grading criteria consider existing riparian zone widths in light of professional experience and judgement as to the ability of those areas to support wildlife movement and dispersal. The existence of barriers to migration and dispersal is evaluated using the FACWet grading criteria edited slightly for applicability to the specific context of the Poudre River corridor.

Analysis of Current Condition
The Poudre River's riparian zone varies widely in its comparative health. Large portions of the riparian zone have been wholly converted by land uses from natural habitat into gravel mines, agricultural fields or urban, residential or commercial developments. The remaining riparian habitat is often stressed by partial or total disconnection from the channel causing a shift in species composition to one tending to favor exotic and/or weedy species and less hydrophytic vegetation. Importantly, floodplain-channel disconnection retards or precludes overbank flooding which drives forest regeneration and provides a rejuvenating force for the riparian habitat in general.

Above the canyon mouth the contributing area to the riparian zone is generally, naturally narrow yet in good condition being managed as public U.S. Forest Service lands. Below the canyon mouth, the river's contributing area has been pervasively modified into a variety of land uses, most commonly agriculture or urban development. Habitat connectivity is uncommonly intact for an urban river such as the Poudre. Above the canyon mouth, most of the riparian zone is intact and barriers are minor. Below the canyon mouth, long stretches of riparian corridor still exist but breaks are common such as where development has encroached to near the river's banks or at bridged road crossings.

The Riparian Condition Indicator grades vary dramatically along the RHAF's reach, virtually from A to F, with metrics possessing concomitant ranges. While extensive familiarity with much of the study area enabled the development of an informed estimate of riparian condition, field assessment using this protocol is beyond the scope of this report and will be performed during the 2016 State of the Poudre study.

Indicator 7: River Form

Grading Guideline Development

River form is the topic of study in the field of fluvial geomorphology[10]. In short, river form is the result of the interaction between the flow, sediment, existing channel, floodplain, and biotic elements. If these elements remain fairly consistent, the system tends to move toward a state of dynamic equilibrium. However, given changes in these elements, the ability to predict the evolution of river form becomes a complex and often uncertain endeavor. Often, evaluating the types of changes will hint at the direction (or relative magnitude) of change, but quantitative predictions of river form are nearly impossible.

The metrics used to asses River Form in the RHAF include planform, channel dimension, and profile. These metrics are modified from the FACStream framework and are based upon foundational theories in fluvial geomorphology. This foundation is then applied to the specific landscape position and context of the Poudre River through the four RHAF river sections.

Analysis of Current Condition

The current condition grade for all three River Form metrics was developed using an "informed estimate."

Canyon: The Poudre River eroded the canyon out of the Rocky Mountain Front Range in this section. The result is a largely confined section of river with some less confined reaches. The most significant constraint to river form is the highway CO-14 paralleling the river along its length.

Transition: From canyon mouth to N. Overland Trail the river maintains much of its historic planform, however between N. Overland Trail and Shields St. the river is entirely constrained by a series of historic and operating gravel mining operations and associated levees. A series of diversion structures disrupt the downstream profile.

Urban: This section has a broad range of constraints, but its river form tends to be strongly controlled by bank hardening, levees, and floodplain development. Downstream profile is influenced by some diversion dams and also grade control structures/bridges. Some sections such as those adjacent to Lee Martinez Park and around the Environmental Learning Center maintain a more natural river form.

Warm: There is less lateral confinement through this section downstream of E. Harmony Rd. Largely adjacent to fields of irrigated agriculture with a handful of grade control structures (diversions or bridges).

[10] Literally: "the study of change of the earth in a river"

Indicator 8: Channel Resilience

Grading Guideline Development

Channel resilience is the ability of the Poudre River to be self-supporting and recover from disturbance events. A resilient ecosystem not only is healthier, but also costs the city of Fort Collins less money in the long term. This indicator was called 'Stability' in the version of FACStream we referenced, but the project team thought the overarching theme of this indicator was more of resilience than a state of constancy. As channel resilience is a holistic indicator (bringing together a large number of channel functions) it is inherently challenging to quantify.

The metrics used to asses Channel Resilience in the RHAF include dynamic equilibrium and channel recovery. Both metrics for channel resilience are modified from the FACStream framework and are based upon foundational theories in fluvial geomorphology. This foundation is then applied to the specific landscape position and context of the Poudre River through the four RHAF river sections.

Analysis of Current Condition

The current condition grade for both the Channel Resilience metrics was developed using an "informed estimate."

Canyon: The narrow and rocky nature of Poudre Canyon inherently limits alterations in the Canyon Section. Much of the larger substrate is colluvium which has fallen into the channel from the hillslopes and will likely never move.

Transition and Urban: The large amount of water diverted from the Poudre for municipal and agricultural use, coupled with a largely developed river corridor, limit the dynamism of the Poudre below the canyon mouth. Also, variable floodplain restrictions, largely in the form of historic and operating gravel mining pits or urban development, may lead to greater channel damage in major flow events since less energy can be dissipated in the floodplain.

Warm: The modified flow regime in this section reduces the channel's capacity for resilience and the finer bed sediments may be more prone to local scour and fill. This section has the most floodplain capacity (increasing overall resilience) of the four RHAF river sections identified in the study, but is characterized by 'pinch points' (e.g. Boxelder Water Treatment Facility, railroad trestles and embankments, I-25 bridge, etc) where the channel itself has a significantly smaller capacity for flows resulting in major changes to flow path.

Indicator 9: Physical Structure

Grading Guideline Development

Physical Structure describes the combined influence of substrate conditions and channel geometry on physical and ecological processes. Physical Structure is evaluated in the RHAF at both a coarse and fine scale. Both are modified from the FACStream framework and are based upon foundational theories in fluvial geomorphology, ecology, and hydrology. This foundation is then applied to the specific landscape position and context of the Poudre River through the four RHAF river sections. The fine-scale physical structure metric is directly built from analyses conducted in the Ecological Response Model (City of Fort Collins, 2014). The grading guidelines for this metric focus on two flow types, fine sediment flushing flow and bed-mobility flows and are captured quantitatively in the grading guidelines for the peak flow metric.

Analysis of Current Condition

The current condition grade for both the Physical Structure metrics is reported as an "informed estimate."

Canyon: In the canyon, the Poudre is a naturally confined river. While the canyon walls naturally limit the river's ability to meander, highway CO-14, which parallels the river, further reduces the ability of the channel to utilize the full width of the canyon, and this affects coarse-scale physical structure. For the safety of water sport recreationalists, large woody debris is not allowed to accumulate in this section. The lack of large woody debris detrimentally affects the coarse-scale structure. Fine-scale structure is estimated to be in a high-quality state as stressors are few and flow regime alteration is minimal in this section.

Transition: In the areas not restricted by gravel pit development, the portions of the Transition section have good coarse-scale structure characterized by mid-channel islands, some side channels and riffle pool morphology and some remnant large woody debris. The constraints imposed upon the lower portions of this section result mainly from a long history of gravel mining and are the reason for the assignment of a grade in the range of B to C.

Urban: This section is primarily characterized by a single thread channel and some reaches have particularly limited off channel habitat. The main exception is the multi-channel reach through the Environmental Learning Center at the lowest end of this section. Management of debris for protection of infrastructure and public safety severely limit the potential for debris damming during flood events on the river in this section. This lack of accumulation of large wood in the channel detrimentally affects the coarse-scale structure. Similar to the transition reach, the combination of a modified flow regime and moderately coarse substrate (median sediment size on the order of 50mm) results in less frequent sediment movement (and its effect on fine-scale structure condition).

Warm: Characteristics of this river section are similar to those in the urban reach with a modest level of improvement to habitat heterogeneity. In this reach, smaller sediment size (on the order of 35mm) allows adequate sediment movement and, therefore, results in a better grade of B+ to B- for fine-scale metric.

Indicator 10: Aquatic and Riparian Wildlife

Each of the five metrics for the Aquatic and Riparian Wildlife Indicator were customized from the FACStream to take advantage of locally available data. The following section addresses each metric separately because the data source and methodology for assessing each differs.

Metric: Aquatic Insects

Most rivers and streams flowing through urban developments have had physical and chemical alterations that can greatly impact aquatic insects through channelization, non-point source pollutants, effluent from the water treatment facilities, and the variety of contaminants associated with urban runoff. The aquatic life in urban streams can also be adversely affected by the replacement of natural landscapes with impervious surfaces, leading to rapid and unnatural increases in stream discharge and elevated non-point source pollution (Nelson 2011, Johnson et al. 2013).

The stress-induced changes on the structure of aquatic insect communities can best be ascertained through analysis of data from a variety of sources. Although some individual submetrics can provide insight into specific types of stress, Bonada et al. (2006) found that the limitations associated with individual submetrics can be improved upon by using multiple metric indices. The analysis of aquatic insect data and comparison between sampling sites provides insight into areas with poorer health of aquatic insects after adjusting to natural spatial changes in community structure.

Grading Guideline Development for Aquatic Insects

During the fall of 2010, the Colorado Department of Public Health and Environment (CDPHE) published specific guidelines for benthic macroinvertebrate sampling and analysis to assist in the evaluation of aquatic life in the State of Colorado (CDPHE, 2010). These guidelines described specific protocols for using a Multi-Metric Index (MMI) in the analysis of aquatic insect data. The MMI was applied to composited quantitative aquatic insect data collected during August of 2013 for the Lower Poudre Monitoring Program.

The MMI provides a single index score based on five or six equally weighted metrics. The group of metrics used in MMI calculations depends on the location of the site and corresponding Biotype (Mountains, Transitional, or Plains). Each of the metrics used in the MMI produces a value that is adjusted to a scale from 1 to 100 based on the range of metric scores found at "reference sites" in the State of Colorado.

The study area covered by existing monitoring program includes two Biotypes defined specifically for macroinvertebrate monitoring (Biotype 1 and Biotype 3). Biotype 1 (called the Transition Zone) includes lower mountain areas of the Colorado Front Range downstream to the lower boundary of the "Front Range Fans" (approximately 1.0 km upstream from the Fossil Creek discharge). Study sites contained within Biotype 1 include PLINC, PROS, USGS and PARCH. All other sites are incorporated into Biotype 3 (Plains), which ranges from the eastern border of the "Front Range Fans" to the eastern border of Colorado. Only the PFOS site at the upper end of Biotype 3 on the Poudre falls within the RHAF. The thresholds that determine attainment or impairment are different for each Biotype. Thresholds for the MMI are shown in Table C.13.

Table C.13: MMI scores required to meet attainment and impairment thresholds specific to local Poudre River biotypes.

Biotype	Attainment Threshold	Impairment Threshold
Transition (Biotype 1)	52	42
Plains (Biotype 3)	37	22

Index scores that fall between the thresholds for attainment and impairment require further evaluation using two additional metrics (Diversity and HBI) in order to determine if the site is in attainment or impaired. Thresholds for these auxiliary metrics are shown in Table C.14.

Table C.14 Thresholds for auxillary metrics required when a score falls between the attainment and impairment thresholds.

Biotype	HBI	Diversity
Transition (Biotype 1)	5.4	2.4
Plains (Biotype 3)	7.7	2.5

Analysis of Current condition

Specific metrics used in the MMI are dependent on site location and corresponding Biotype. Metrics currently recommended for Biotype 1 include: Percent Non-insect Taxa, EP Taxa, Percent Chironomidae, Percent Sensitive Plains Families, Predator-Shredder Taxa, and Clinger Taxa. Metrics currently recommended for Biotype 3 include: Insect Taxa, Percent Non-insect Taxa, Percent Sensitive Plains Families, Percent Dominant Taxa, Predator-Shredder Taxa, and Sprawler Taxa. These metrics were employed at the appropriate site locations to assist in data analysis. The MMI was developed specifically for aquatic insects data collected during the late summer or fall seasons, so data from the spring was not evaluated using the MMI. Results from the Poudre MMI for sample year 2013 are presented in Figure C.2 below. The grading guidelines reference the MMI and specific values for the Biotype 1 as the majority of the study area falls within Biotype 1.

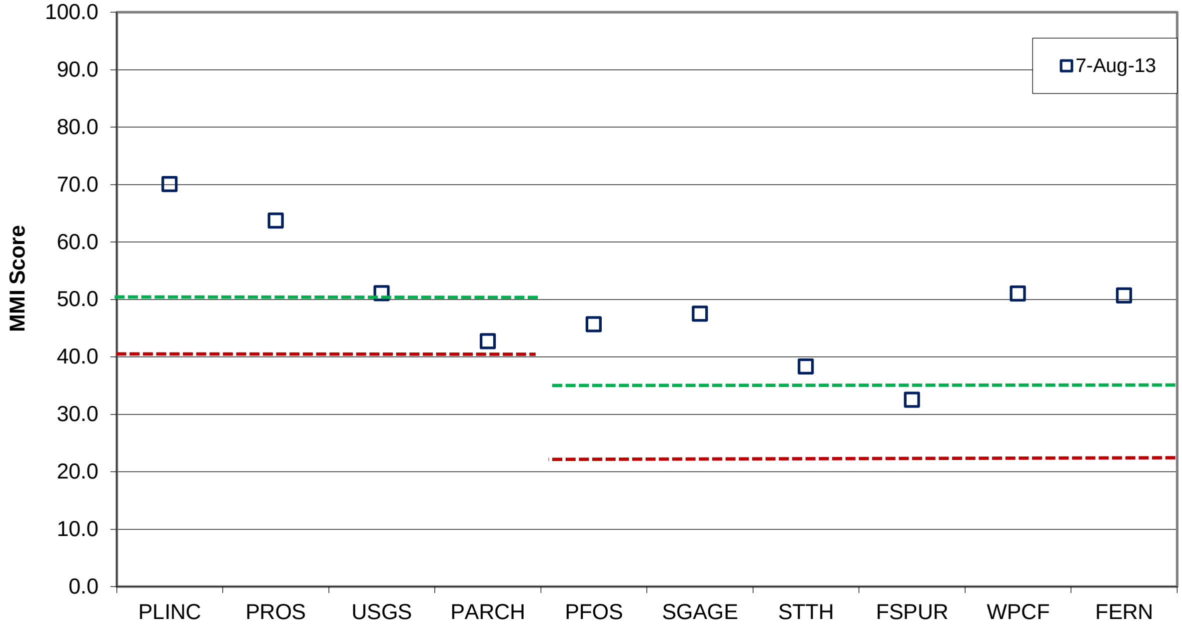

Figure C.2 Results of MMI analysis for 2013. The biotype and associated thresholds change between sites PARCH and PFOS. The green dotted lines indicate the attainment threshold and the red dotted line represents the impairment threshold.

Metrics: Native Fish and Trout

The grading guidelines for fish were developed by CSU's Dr. Kevin Bestgen and fisheries biologists from the Colorado Parks and Wildlife (CPW). Collectively these biologists have extensive knowledge of the fisheries in the Poudre through years of local data collection as well as expert working knowledge of Colorado fish populations, trends and stressors.

Grading guideline development

The grading guidelines for native fish were developed specifically for warm water fish found in the RHAF Urban and Warm water sections. The grading guidelines for trout consider the cooler water sections of the RHAF study area including: the Canyon, Transition and Urban sections. The upper and lower ends of the RHAF Urban section (from Shields St. to the confluence with Boxelder) represent the natural habitat limits for native fish and trout respectively. Temperature is the primary factor influencing these natural habitat boundaries.

Responses of fish communities are integrative of a host of watershed conditions that are manifest as population responses over time. Changes in native fish communities and the Poudre River trout fishery are of interest because they reflect the relative health and condition of the system. Data that describe the biota and water chemistry of the warmer sections (from Fort Collins to near Greeley) have been collected over relatively long periods with a goal to monitor water quality of the Poudre River. Therefore, some of those data used to inform the grading guidelines describe the fish communities of the Poudre River near Fort Collins and help us understand trends in species richness and abundance of native fishes and salmonids (mostly brown trout) related to stream flow patterns and habitat changes over time.

Data were collected in these reaches from 1993–present. Data from an upstream site, which was adjacent to McMurry Natural Area and Martinez Park (Site #1 in Bestgen and Fausch, 1993), were used to draw inferences about Brown Trout abundance and dynamics. The second site, near the ELC (Site #3 in Bestgen and Fausch, 1993) provided data on Native Fish (Brown Trout were rare there). Additional information from CPW's South Platte Basin native fish inventory efforts provided data on native fish population dynamics. These data were comprised of three historic sampling sites located at 0.5 miles downstream of Lemay, the Timberline Bridge, and the Environmental Learning Center.

Grading guidelines for trout are based on brown trout populations and trends due to stressors such as whirling disease that have eliminated other trout species. However, given the aggressive and adaptable nature of brown trout, establishment of self-sustaining populations of other cold water dependent trout such as cutthroat and rainbow trout is desirable (yet challenging) and therefore they are specifically identified in the "A" grade.

Analysis of Current Condition

The current condition for both native fish and trout come directly from the data sources described above.

Metric: Aquatic Habitat Connectivity

Aquatic habitat connectivity, or conversely fragmentation, affects many aspects of a species' ability to thrive. Fragmentation can limit the ability to meet essential habitat needs including support of the food chain, reproductive cycles, healthy population genetics, and seasonal migration. Connectivity of habitats also provides opportunities for fish to use side channels and backwater habitats as refugia from predators or during large flood events.

Thirteen structures impede fish passage in the Poudre from the canyon mouth and I-25 (Figure C.3).

Grading Guideline Development and Analysis of Current condition

The grading guidelines are based on river lengths. The highest grade of "A" refers to 20 connected river miles because trout have been recorded migrating seasonally up to this distance. Each subsequent lower category is half the distance. Less information is known about the migration needs of native fish. Even so, experts agree when the habitat is fragmented to as little as 1-2 miles native fish will be adversely impacted. In fact, over the past two decades fish monitoring programs have recorded a local loss of species which is likely the result of multiple factors including fragmentation and associated lack of habitat mosaics (e.g, coarse-scale physical structure).

The current condition grades are derived through a direct evaluation of current infrastructure for each RHAF section.

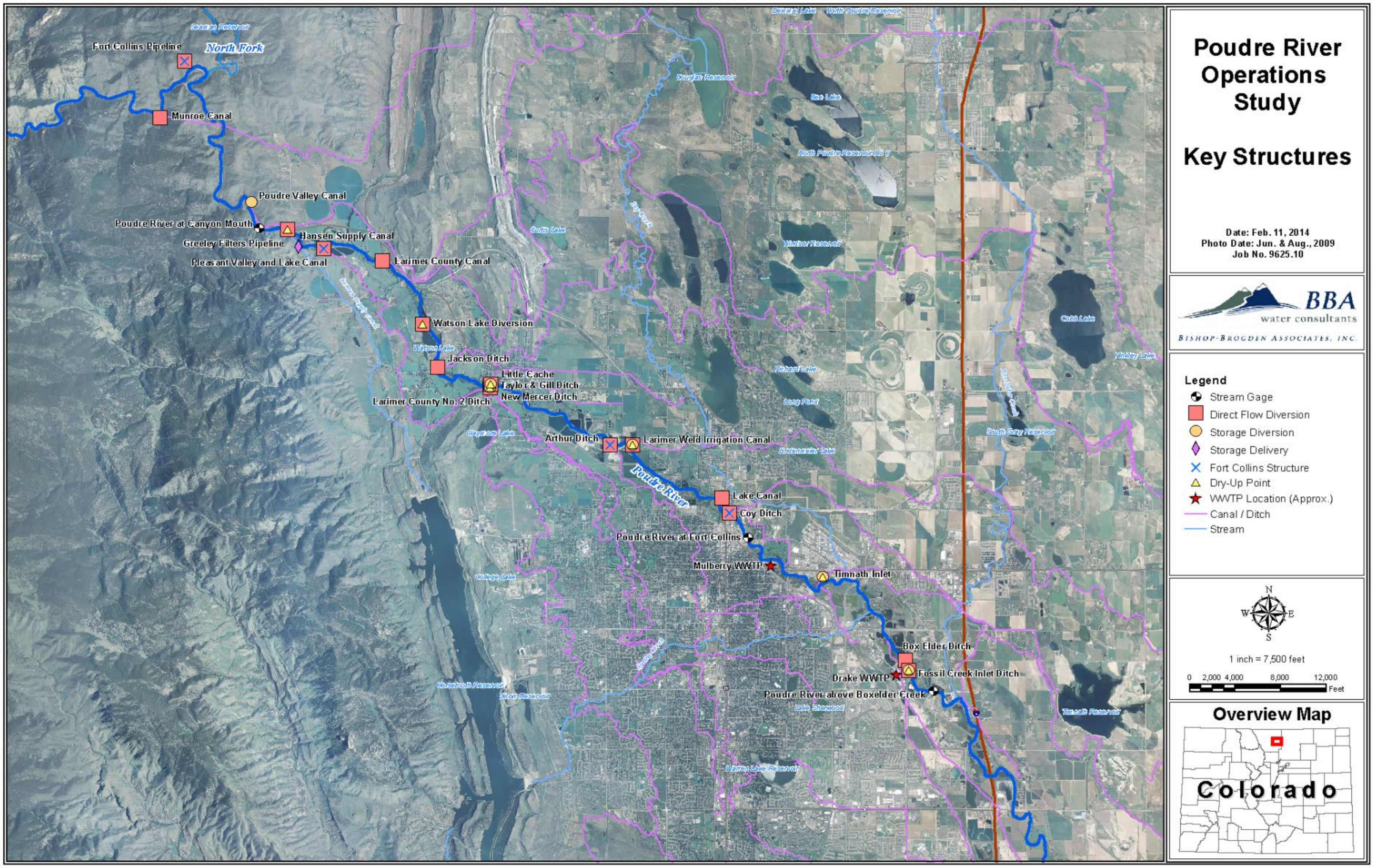

Figure C.3 Map of the key structures in the Poudre in the RHAF study area. Thirteen structures impede fish passage along this reach. Figure originally produced in the Poudre River Operations Study (Brogden-Bishop Associates, 2014)

Metric: Birds

Riparian ecosystems along the Colorado Front Range are ribbons of habitat that host the richest avian diversity in the state, but only represent 3% of the Colorado landscape (Kingery, 1998). The habitat structure of lowland riparian forests is characteristically heterogeneous and supports species that utilize different types of habitat structure. The grading guidelines for this metric were developed based on the concept that certain species are representative of riparian habitat structure(s) and their presence or absence is indicative of habitat condition.

Species were selected as an indicator species if they are most likely to thrive in the associated riparian habitat even though they may also inhabit other areas. For example, species such as Yellow Warbler, Western Wood-Pewee, House Wren, and Bullock's Oriole may be considered generalists. Yet these species will rarely be detected at any significant level beyond the river corridor in the highly altered upland environments.

Twelve indicator species were selected to communicate habitat condition: Gray Catbird, Common Yellowthroat, Yellow-breasted Chat, Western Wood-Pewee, Bullock's Oriole, Yellow Warbler, House Wren, Song Sparrow, Black-capped Chickadee, Western Kingbird, and Eastern Kingbird. The City of Fort Collins Natural Areas Department conducted breeding bird surveys along the Poudre River from LaPorte south to I-25 in 2009, 2010, and 2014. This data set provides an inventory of species, distribution, and abundance.

Research indicates, as development encroaches on lowland riparian habitats, the accompanying exotic species may lead to an increase in tree height, diversity, and density occurs (Miller et al. 2003, Miller and Hobbs, 2000). This results in a more continuous canopy structure that may adversely affect species that rely on gaps in the canopy for foraging and daily functioning. Additionally, this altered species composition combined with armoring of river banks, causes the percentage of native shrub species to decrease creating an understory where open habitat becomes more prevalent. The native shrub component is usually high in diversity and density and attractive to a variety of avian species. Based on results of the monitoring program, it appears this habitat structure is not well represented along the Poudre River. Riparian shrub communities are normally composed of wild plum, snowberry, hawthorn, boxelder, chokecherry, and willow species. Grey Catbird and Yellow-breasted Chat are species that with a high dependency specifically on this habitat type (Miller et al. 2003).

Grading Guideline Development and Analysis of Current Condition

Grading guidelines and current condition grades draw directly on the presence of Indicator species and rely directly on the aforementioned breeding bird survey.

References for Appendices

Army Corps of Engineer, 2015. Supplemental Draft Environmental Impact Statement for the Northern Integrated Supply Project. Common Technical Platform Hydrology data,(Run 1). Written communication with J. Urbanic on July 17, 2015.

Bishop-Brogden Associates, 2014. Poudre River Operations Study. Prepared for the City of Fort Collins, Natural Areas Department.

Beardsley, M., B. Johnson and J. Doran. In Prep. Functional Assessment of Colorado Streams (FACStream) Method. Report to be submitted to US Environmental Protection Agency and the CO Water Conservation Board. Personal communication with M. Beardsley on Jan. 10, 2015 and July 7, 2015.

Bestgen, K. R., and K. D. Fausch, 1993. Status and trends of the fish community at 10 sites in the Cache la Poudre River, from Fort Collins to Greeley, Colorado, 1970-1992. Final Report Eastman Kodak Company and City of Fort Collins, 107 pp.

Bonada, N., N. Prat, V. H. Resh and B. Statzner. 2006. Developments in aquatic insect biomonitoring: A comparative analysis of recent approaches. Annual Review of Entomology, 51: 495-523.

Bunn, S. E. and A. H. Arthington. 2002. Basic Principles and Ecological Consequences of Altered Flow Regimes for Aquatic Biodiversity. Environmental Management 30(4), 492-507 pp. doi:10.1007/s00267-002-2737-0.

City of Fort Collins. 2014. Ecological Response Model for the Cache la Poudre River through Fort Collins. Ecological Response Modeling Team.

Colorado Department of Public Health and Environment. 2010. Aquatic life use attainment: Methodology to determine use attainment for rivers and streams. Policy Statement, 2010-1.

Colorado Department of Public Health. 2012. Colorado's Section 303(d) List of Impaired Waters and Monitoring and Evaluation List, Regulation No. 93, 5 CCR 1002-93.

Colorado Department of Public Health and Environment. 2013. Basic Standards and Methodologies for Surface Waters. Regulation No. 31, 5 CCR 1002-31.

Colorado Department of Public Health and Environment. 2014. Classifications and Numeric Standards for South Platte River Basin, Laramie River Basin, Republican River Basin, Smoky Hill River Basin. Regulation No. 38, 5 CCR 1002-38.

Cushman, R. M. 1985. Review of Ecological Effects of Rapidly Varying Flows Downstream from Hydroelectric Facilities. North American Journal of Fisheries Management 5(3A), 330-9 pp. doi:10.1577/1548-8659(1985)5<330:ROEEOR>2.0.CO;2.

Kingery, H.E. ed., 1998. Colorado Breeding Bird Atlas. Colorado Bird Atlas Partnership, Denver, CO.

Johnson, R.C., H. Jin, M.M. Carreriro and J.D. Jack. 2013. Macroinvertebrate community structure, secondary production and trophic-level dynamics in urban streams affected by non-point-source pollution. Freshwater Biology, 58: 843-857.

Lemly, J. and L. Gilligan. 2013. Ecological Integrity Assesment (EIA) for Colorado Wetlands Field Manual, Version 1.0. Report Submitted to the US EPA and Colorado Parks and Wildlife.

Milhous, R. T. 2009. An adaptive assessment of the flushing flow needs of the Lower Poudre River, Colorado: First evaluation. Proceedings: Hydrology Days, 46-56 pp.

Milhous, R. T. 2012. Flushing flows, sediment transport, and channel maintenance in gravel and cobble bed rivers: Poudre River case study H. Mader and J. Kraml (eds.). Paper presented at 9th International Symposium on Ecohydraulics 2012, Vienna, Austraia.

Miller, J. R. and N.T. Hobbs. 2000. Recreational trails, human activity, and nest predation in lowland riparian areas. Landscape and Urban Planning 50, 227-236.

Miller, J. R., J. A. Wiens, N.T. Hobbs and D.M. Theobald. 2003. Effects of Human Settlement on Bird Communities in Lowland Riparian Areas of Colorado. Ecological Applications 13, 1041-1059

Nelson, M.S. 2011. Response of stream macroinvertebrate assemblages to erosion control structures in a wastewater dominated urban stream in the southwestern U.S. Hydrobiologia, 663: 51-69.

U.S. Geological Survey, 1982. Guidelines for determining flood-flow frequency: Bulletin 17B of the Hydrology Subcommittee, Office of Water Data Coordination, U.S. Geological Survey, Reston,Va., 183. Accessed online on 7/4/15 at http://water.usgs.gov/osw/bulletin17b/bulletin_17B.html

Wilcock, P. R., G. M. Kondolf, W. V. G. Matthews and A. F. Barta. 1996. Specification of sediment maintenance flows for a large gravel-bed river. Water Resources Research, 32(9), 2911-21 pp.