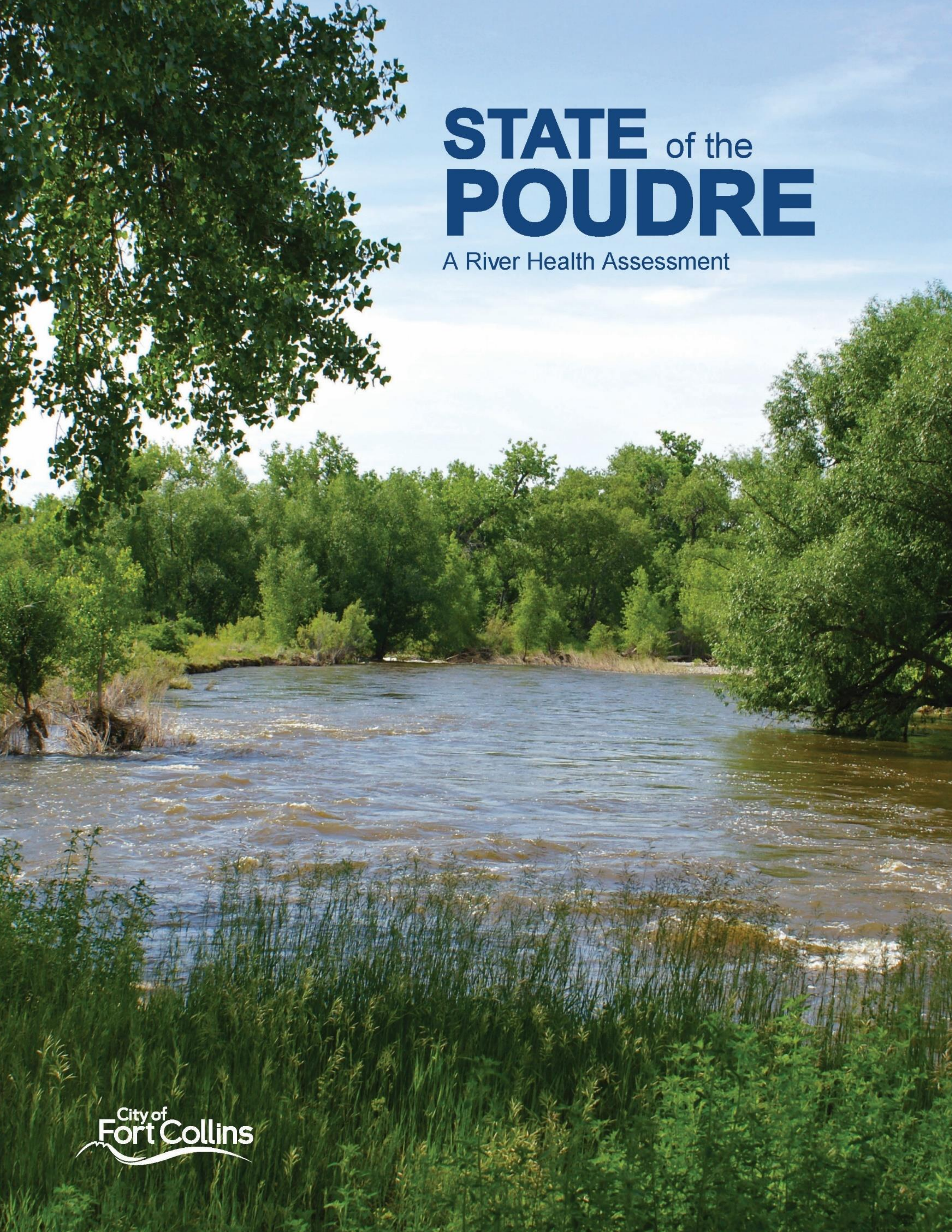

STATE of the POUDRE

A River Health Assessment

City of Fort Collins

Executive Summary

The purpose of this first State of the Poudre River (SOPR) is to provide a description of the current health of the Cache la Poudre River (Poudre) from approximately Gateway Natural Area to I-25. The Poudre is a complex natural system that has been altered by nearly two centuries of human influence. This has resulted in dramatic changes to the physical structure of the river, water quantity and quality, floodplain, forests, and wildlife communities. The human footprint continues to expand, placing additional pressure (or stresses) on the river ecosystem and the natural processes that sustain it. This river health assessment provides the City of Fort Collins with a new tool to track trends and benchmark progress towards its vision of sustaining a healthy and resilient Cache la Poudre River.

While the Poudre flows 126 miles from its headwaters to its confluence with the South Platte near Greeley this study focuses on a 24-mile reach from the lower canyon through Fort Collins. The study area was divided into four zones (Canyon, Rural, Urban, and Plains) and further into 18 study reaches based on natural changes on the landscape and human influences.

Overall Grade: For the 24-mile study area the Poudre River received an overall grade of C. This grade indicates the even though the Poudre has been altered and degraded by a suite of local and system wide stresses that impair its health, it continues to support basic elements of a functioning river ecosystem.

The framework for this baseline assessment includes nine indicators of river health which are informed by 25 indicator-specific metrics. Collectively these provide a thorough evaluation of how well the system is functioning. Metrics grades are developed by collecting and incorporating many types of data, which were then translated into an A-F grading system. Indicator and metric numerical scores and their corresponding letter grades were calibrated to categorical definitions relating to degree of functionality or impairment.

Recommended ranges developed for each metric (as established in the River Health Assessment Framework, City of Fort Collins, 2015) and were developed based on the City's concept of working towards a functioning river ecosystem. The recommended ranges consider the contemporary real-world context and reasonable expectations for future change and the potential for improvement. They should, however, be used as a guide and aspiration rather than a directive. Also, when interpreting results for a comprehensive scientific assessment such as this, it is important to consider that uncertainty and variability exists across scientific disciplines, data sources, and river reaches. The methods and grading guidelines provide an explicit description of the analytical approaches used and can help the reader understand this variability.

This report is structured to allow the reader to understand the project approach (Sections 1 and 2) followed by identification of potential influences, or stressors, on river health in Section 3. The health assessment scores (Section 4) reveal the ramifications these anthropogenic stressors are having on ecosystem condition. Results indicate there is considerable variability across aspects of river health as scores vary widely (from A to F) at smallest unit of measurement (metrics scores by reach). In Section 5, the focus shifts to an overview of river health, describing the link between stressors and degree and type of impairment for each of the four zones. Poudre River health indicator grades for each zone are compared to the ranges recommended in the City's Poudre River Health Assessment Framework (2015)—to highlight areas where there is the greatest gap between the City's goals for the river and today's conditions. This section also includes an analysis of the causes of impairment and explores which problems are tractable to practical solutions. Section 6 looks toward the potential future applications and improvements for the project.

Key findings by topic

- The Poudre is characterized by major changes in flow volumes and timing. Reductions have significantly altered peak and base flows, the effects which are exacerbated the further one travels downstream. Diversions also cause unnatural fluctuations in flow volume, which likely affects critical habitat and reproductive needs of fish and insects in the river.

- The river channel has seen drastic changes over the past two centuries causing widespread fundamental alterations to the ecosystem. The river used to meander across the floodplain. Forcing it into a single, permanent path has disrupted various processes dependent on natural river movement including the regeneration of riparian forests, the movement and balance of sediment, the river's resilience to large floods, and other events like wildfires in the upper watershed. However, with today's land uses, there is a need to protect infrastructure in the floodplain. Understanding this new physical dynamic and its relationship with extreme flow events is central to successful management for river health.

- Water quality in the Poudre is quite good, despite the presence of some stresses, and is supported by the City's commitment to manage stormwater runoff and meet regulatory requirements for treated wastewater effluent. The City and others closely track water quality, implementing quick action if undesirable changes are detected.

- While non-native trout are thriving in Poudre's cooler waters (generally upstream from College Avenue) the populations of native fish are in sharp decline. These declines are most likely due to fragmented habitat and extended periods of extremely low base flows. Other stresses likely influencing fishery health include rapid fluctuation of flows, non-native predatory fish and altered water temperatures.

- The riparian corridor has experienced a system-wide disconnect between the river and its floodplain. In many places riverside forests form only a narrow band that hugs the river banks providing little support for overall river health. However, where the riparian corridor is connected to the river there are pockets of healthy forests including a mosaic of diverse habitats, which are ideal for supporting wildlife. Restoring the river-floodplain connection and active management of aggressive non-native trees is making a positive difference across City-owned floodplain properties.

Zone Highlights

Canyon zone: B- (Munroe tunnel, above Gateway Natural Area, to the canyon mouth)

Through the Canyon zone the river and riparian corridor are confined by canyon walls. Highway 14 further limits the river's space and ability to mitigate large floods. Here the river supports aquatic life, a narrow riparian forest, and floodplain, but this zone marks the beginning of an approximately 20-mile reach of river that is heavily impacted by multiple diversions which begin to reduce flows and fragment aquatic habitat. The upstream forested watershed provides the City and surrounding communities with a reliable and high quality drinking water source, but in the lower Canyon zone warming water temperatures emerge as a potential concern for aquatic life.

Rural zone: C (Canyon mouth to just below Overland Road)

As the Poudre leaves the canyon the river has its first opportunity to connect to a wider floodplain, but impacts from berms, armored banks, and channelization disconnect the river from its floodplain. Native cottonwoods dominate many riverside forests; however, encroachment from agricultural lands affects the health of the vegetation. Cooler waters released from Horsetooth Reservoir lower water temperature in this zone. The impact of multiple large water diversions severely alters peak and base (low) flows.

Urban zone: C (just below Overland road to Timberline Road)

Gravel pits and associated berms affect the river's ability to access the floodplain on the upstream end of the Urban zone, while encroachment from roads and development through the City have impacted the diversity and extent of the riverside forests and habitats. Nevertheless, pockets of excellent riverside forests exist (near Shields Street) where high spring flows have access to the floodplain. The river once formed multiple braided channels increasing the system's capacity to mitigate large floods, but now as a single, confined channel it has reduced resilience to flooding. Diversion dams and the lack of large wood in the channel negatively impact habitat for aquatic insects and fish. While introduced non-native trout appear to be doing well, a major concern is the local loss of native fish.

Plains zone: C (Timberline Road to I-25)

As the river flows through large areas of land managed as conserved open lands river health improves slightly in the Plains zone. Yet the legacy of land use and water diversions continues to have a significant influence on river health. Diminished peak flows and significantly impacted base flows have created a smaller-than-natural river channel that is frequently disconnected from its floodplain. Low numbers and diversity of native fish are a major concern, but fish passage structures allow for better aquatic habitat connectivity.

So what?

A “B” grade for river health is desired to fulfill the City’s vision for a healthy and resilient river. This holistic and science-based river assessment can help the City evaluate operational, management, and policy options for preserving or enhancing the river’s health. This assessment can also serve as a benchmark for monitoring river health and changes in the future. Broader communication and engagement of diverse Poudre River stakeholders can strengthen our ability to manage for a healthy river now and in the future.

This report presents and discusses the comprehensive set of projects findings. Other project components (a summary report card and online mapping tool) are available at: www.fcgov.com/poudrereportcard.

2016-2017 State of the Poudre project team

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City of Fort Collins, 5/24/2017

Glossary

Alluvial channel – a stream or river channel with soft bed and banks that maintains form through dynamic equilibrium between the forces of erosion and deposition. (See **threshold channel**.)

Armoring (bed) – the formation of a more scour-resistant layer of large particles on the surface of a river bed.

Armoring (channel) – the application of resistant materials on a river bed or banks for to reduce scour and erosion.

Augmentation (of flow) – addition of water to a system. (See **depletion**.)

Avulsion – the sudden change of river location. (See **migration**.)

Benthic macroinvertebrates – often referred to in this report simply as "aquatic insects", benthic macroinvertebrates refers to insects and other small invertebrate (without backbone) organisms that live in or on the river bed.

Channel maintenance flows: Flows large enough to initiate scour and deposition processes, including associated channel migration, which in turn maintain river conveyance capacity by scouring encroaching vegetation within the bankfull channel.

Channelization – mechanical alteration of a river or stream that confines flow within a single course. Often times these actions can be combined with planform straightening.

Depletion (of flow) – removal of water from a system (See **augmentation**.)

Embeddedness – the degree to which interstitial spaces between river substrate particles are filled with fine sediment. (See **interstitial space.**)

Encroachment – the intrusion of artificial structure, development, or land use on the floodplain or riparian zone. A second use of this word is when vegetation encroaches or moves into the existing active river channel.

Entrenchment – the degree to which river flows are vertically contained within a channel.

Flushing – the mobilization of sediment particles from the river bed substrate matrix by the physical force (referred to as shear stress) of moving water.

Flushing flows- the mobilization of median bed size material to support habitat and life cycle needs of aquatic insects and fish that rely on clean interstitial space.

Geomorphic (geomorphological) – relating to the form of the land or topography.

Interstitial space – the open space between particles, here referring specifically to open spaces in the river bed between substrate particles.

Mainstem – the principal or dominating stream or river in a drainage, in this case, it refers to the Cache la Poudre River.

Migration – the gradual change of river location. (See **avulsion**.)

Reach – a discrete segment of river between two points. In this study, 18 discrete reaches are defined for the purpose of assessment.

Riparian zone – the area between a stream and adjacent upland that whose vegetation and hydrology depend on the stream**.**

Threshold channel – a stream or river channel with hard bed and banks that maintains form by resisting erosion. (See **alluvial channel**.)

Metric definitions

The definitions provided below are intended to explain each metric concept in general terms. Definitions specific to this study for each metric are presented in Appendix A. Metrics are listed per the structure of the Poudre River Health Assessment Framework.

Peak flows occur when the river is at its highest flow; usually in the late spring or early summer.

Base flows are the low flows that occur during drier times of the year – diversions can cause base flow-like conditions at uncharacteristic times of the year.

Rate of change of flow describes how fast diversions lower or increase the quantity of water in the river channel.

Land erosion considers the amount of sediment produced in the watershed by hillslope processes and land uses resulting in exposed soils.

Channel erosion includes sediment production caused by channel erosion along the mainstem and its tributaries.

Sediment transport represents the ability of the river to export sediment from a reach in balance with what is coming in.

Water temperature compares the monitored temperature of water in the river with applicable water quality standards.

Nutrients examines overall load of water-quality impairing elements and compounds, most commonly involving nitrogen and/or phosphorous.

pH of water is a measure of its acidity or alkalinity.

Dissolved oxygen content is the density of oxygen in the river's waters, measured in milligrams/liter.

Floodplain extent is the amount of 5-year floodplain remaining in the SOPR riparian zone.

Vegetation structure and complexity considers the composition and condition of four habitat strata, canopy, sub-canopy, shrub, and herbaceous, along with patchiness and interspersion, and native forest regeneration.

Habitat connectivity examines the amount of natural or semi-natural habitat in the SOPR riparian zone and the ease with which animals can move through the riparian corridor.

Contributing area evaluates the ability of the area within 200m of the SOPR riparian zone to support or degrade river health, as a result of land use and land cover

Planform refers to the 'bird's eye' view of the river and describes the degree of branching and sinuosity.

Channel dimension focuses on the cross-sectional shape of the channel which 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.

Dynamic equilibrium is the long-term (decadal) tendency for a river to maintain its form or character under a characteristic flow and sediment regime.

Channel recovery 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.

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.

Fine-scale physical structure evaluates the amount and diversity of microhabitats within the reach, primarily bed materials and algae.

Aquatic insects considers the abundance of indicator taxa against desired amounts.

Aquatic habitat connectivity is the degree to which a zone is segmented by cross-channel structures, usually related to diversions.

Acronyms

303(d)	The 303(d) list of impaired waters in Colorado as defined by Colorado Department of Health and Environment
cfs	cubic feet per second
CDPHE	Colorado Department of Public Health and Environment
CPW	Colorado Parks and Wildlife
CSU	Colorado State University
CSU-LFL	Larval Fish Laboratory at CSU
EP	Ephemeroptera and Plecoptera (mayfly and stonefly; sensitive taxa)
ELC	Environmental Learning Center
ERM	Ecological Response Model
FACStream	Functional Assessment of Colorado Streams method
HEC-RAS	Hydraulic Engineering Center— River Analysis System
LiDAR	Light Detection and Ranging (a remote sensing method)
m	meters
MMI	Multi-Metric Index (used for aquatic insects)
MWAT	Maximum weekly average temperature
RHAF	River Health Assessment Framework
SOPR	State of the Poudre River

Table of Contents

1 Introduction and overview

1.1 Introduction

This State of the Poudre River (SOPR) report is an ecological assessment of current-day river health, designed to represent a wide range of legacy and modern-day influences. A healthy Poudre River corridor offers many important social, environmental and economic benefits to the City of Fort Collins. Maintaining river health is directly addressed in City's guiding strategic document, Plan Fort Collins, which states that the City will work towards "*…sustaining a healthy and resilient Cache la Poudre River*" (City of Fort Collins, 2010). The methods used in this river health assessment are detailed in the Fort Collins River Health Assessment Framework (RHAF) (City of Fort Collins, 2015).

The SOPR details the results of the first health assessment for the Poudre River. Two related products provide other avenues for audiences to engage with the results from this project. The River Health Report Card is a succinct, colorful summary of key findings and river health grades. An online mapping tool allows audiences to explore the assessment results at various spatial scales and on specific topics of interest. All elements of this project are available at fcgov.com/poudrereportcard.

The Cache la Poudre River (Poudre) runs approximately 126 miles from its headwaters in Rocky Mountain National Park to its confluence with the South Platte near Greeley. The study area of this assessment is limited to the section of river that most directly influences Fort Collins and extends from the City's water supply intake— near Gateway Natural Area in the lower Poudre Canyon — to Interstate-25.

1.2 Why assess river health?

The Poudre and its riparian floodplain habitat are a naturally complex system that have been altered by nearly two centuries of modern human use, resulting in dramatic changes to water quantity and quality, physical structure of the river and floodplain, riverside forests, and wildlife communities. Today, our human footprint continues to expand, placing added pressure on the river ecosystem and the natural processes that sustain it.

The City, across its many departments and divisions, is involved in a variety of projects and planning efforts that affect the river in many ways. This work is often aimed at mitigating specific, known stresses or enhancing particular benefits, also known as *watershed services*. Watershed services include the provision of consistent and clean water supplies, flood mitigation, fish and wildlife habitat, and diverse recreational opportunities (Figure 1.1).

The task of understanding, managing, and communicating the health of this complex system becomes increasingly important as the pressures that threaten its health and function also continue to grow. However, historically, there has not been a centralized or structured way to measure the collective impact of the City's efforts on the overall health of the river. To address this need, the City of Fort Collins Natural Areas and Utilities Watershed Program have developed this first holistic ecological assessment of Poudre River health. It will provide the City with a comprehensive reflection of ecosystem health, enabling the City to benchmark progress towards achieving and sustaining river health in the broader context of sustaining watershed services.

By integrating hydrological, chemical, geomorphic (physical), and biological data into a holistic assessment of river health, this project provides a common platform for tracking river health in meaningful and measureable ways. A useful aspect of the SOPR is that it is easy to interpret at all levels of technical experience. It incorporates a wide range of information into a river health grades and uses the common A through F academic-type grading system. To track changes in river health over time, the SOPR assessment should be conducted periodically (every 3 to 5 years).

This accessible communication platform can expand stakeholder involvement and enhance dialogue around river management. Engagement of diverse interdepartmental and regional stakeholder groups can strengthen our collective efforts toward the goal of managing for a healthy Poudre River and illuminate opportunities to improve watershed services

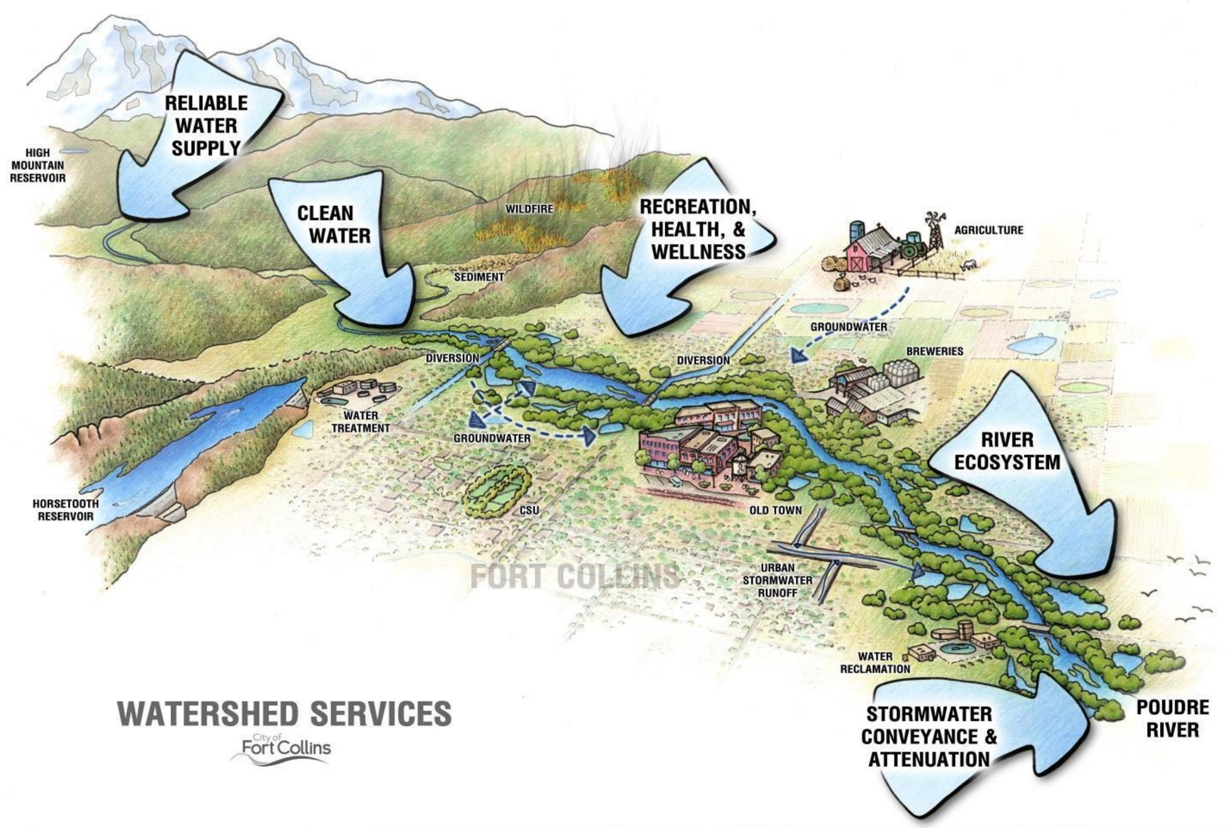


Figure 1.1: The watershed services provided by the Poudre River include consistent and clean water supplies, flood mitigation, fish and wildlife habitat, and recreational opportunities.

1.3 Community benefits of a healthy and resilient river

Figure 1.2: A healthy and resilient river is a river that sustains basics functions (such as water quality) during the years with average precipitation and also provides protective benefits such as (floodwater attenuation and infrastructure protection) during extreme wet or dry years.

The *health* of the river system is a reflection of its ability to perform its normal suite of functions, thereby providing the benefits our community values and depends upon (Figure 1.2). *Resilience* of the Poudre River is interpreted from two perspectives in this assessment:

- As a component of long-term river health, resilience is the ability of the system to maintain or regain its fundamental characteristics and functions after a major disturbance such as an extreme flood, drought, or fire.
- From the human point of view, resilience is the ability of communities to keep functioning during and after major disturbance or natural disasters. In this sense, resilient systems are those where human safety and infrastructure are not threatened by the river's response to disturbance.

The 2013 flood event provided excellent examples of river and community resilience across the Colorado Front Range. In general, reaches where rivers had ample natural floodplain capacity and room to move and adjust recovered quickly after the floods, and damage was minimal. Reaches where floodplain development and infrastructure relied on artificial stabilization tended to have the greatest river health impacts and the most infrastructure damage.

2 Methods

2.1 River health is measured through function

In taking a functional approach to understanding river health, the underlying question is not how the ecosystem looks, but rather, how well the system is functioning. A functional assessment conveys information about the condition of, and inter-dependencies between, many different components of the river ecosystem. It affords the advantage of not only revealing the current stressors (human impacts- past or present- that impair river health), but also how management actions and other changes may affect the future health and resilience of the river. The methods used herein are adapted from the Functional Assessment of Colorado Streams (FACStream) protocol (Beardsley, et al. 2015) and are fully documented in the City's "*River Health Assessment Framework" (*City of Fort Collins, 2015).

The River Health Assessment Framework (RHAF) is structured around ***indicators*** of river health which are informed by indicator-specific ***metrics***, to provide a thorough evaluation of how well the system is functioning. Indicator and metric scores and their corresponding grades were calibrated to categorical definitions relating to the degree of functioning or impairment (Table 2.1). The grade ranges take into consideration the conditions necessary to support a functioning river ecosystem in the contemporary context with reasonable expectations for future change and potential improvement. An A grade represents the highest level of functionality and F the lowest.

Table 2.1: General guidelines used for calibrating indicator and metric grades in the Poudre River Health Assessment Framework.

Grade	Score	Descriptor	Explanation
A	90 – 100	Reference standard	Condition of the indicator or metric is self-sustaining and supports functional characteristics appropriate to sustain river health. Little or no management is needed to sustain and protect this level of function, given the minimal from the modern landscape.
B	80 – 89	Highly functional	Condition maintains essential qualities that support a high level of function, but there is some influence of stressors at a detectable, yet minor, level. Requires limited management to sustain and protect against stressors.
C	70 - 79	Functional	Condition is altered by stressors that substantially impair functionality, basic natural river functions are still sustained. Periodic, and at times intensive, management is required maintain the river's functional role.
D	60 - 69	Functionally impaired	Condition is severely altered by stressors that impair basic natural river functions and the overall health of the river. Active management is required to maintain the river's functional role.
F	50 - 59	Non-functional	Condition is profoundly impaired by massive or overwhelming stressors that render it incapable of supporting basic natural river functions or it is otherwise unable to sustain biological river communities.

These reference definitions provide direction and the foundation for development of metric specific grading guidelines which are presented in full in Appendix A.

The final step in development of the RHAF was to determine a recommended range for each metric that, if achieved, would contribute to an overall healthy and functioning system. These recommended ranges are reproduced in Section 5 of this report to provide context that will convey a picture of today's river conditions compared to conditions needed for a healthy river. It is important to note that while these recommended ranges represent a goal to work *towards*, they are not an edict or mandate for the City. Initiatives aimed at improving any specific metric must be considered within the context of other City goals, as well as legal and jurisdictional limitations. River health goals can at times or in specific places be in conflict with other City goals which may take priority, particularly for the provision of essential services such as drinking water, public safety, and protection of infrastructure.

2.2 Assessment framework

The framework consists of nine indicators and 25 metrics (Table 2.2). Some refinements of the original Poudre RHAF were implemented during this assessment in response to data availability and field trials (these changes are outlined in Appendix B). This SOPR baseline assessment is the first application of the Poudre RHAF and it represents a snapshot of the river's health during the 2015 and 2016 period.

Table 2.2: Summary of indicators and metrics included in the State of the Poudre River baseline assessment.

Indicator	Metrics
Flow regime	Peak flow, base flow, rate of change
Sediment regime	Land erosion, channel erosion, continuity
Water quality	Temperature, pH, nutrients, dissolved oxygen
Floodplain connectivity	Floodplain extent
Riparian condition	Vegetation structure, habitat connectivity, contributing area
River form	Planform, dimension, profile
Resilience	Dynamic equilibrium, recovery potential
Physical structure	Coarse-scale structure, fine-scale structure
Aquatic life	Aquatic insects, aquatic habitat connectivity, native fish, trout

The RHAF indicators serve as the framework to organize information from river-related scientific disciplines and to make it easier to understand the ramifications for river health. The metrics are the backbone of the RHAF and represent aspects of the river ecosystem which can be practically measured. They are defined in the RHAF and the grading guidelines for each metric are provided in Appendix A; an abbreviated list of metric definitions was also included in the glossary as a quick reference to assist readers throughout the rest of this document.

Figure 2.1: Team member and geomorphologist, Johannes Beeby, conducts a rapid assessment of the river form, resilience and physical structure metrics.

2.3 Study area

The SOPR study area encompasses the Poudre River and its associated riparian area from just upstream of the Munroe Diversion (above Gateway Natural Area in the Poudre canyon) to Interstate 25. The river varies greatly through the study area with a range of geologic and ecological settings and different types of human influence. To account for this variability and meaningfully convey the state of the Poudre River, the study area was divided into four zones: Canyon, Rural, Urban, and Plains. These four zones were further subdivided into a total of 18 reaches to define relatively homogenous assessment units (Figures 2.2. 2.3, Table 2.3)

As a natural ecological transition zone, the changes that occur to the river through the SOPR study area are extensive and even greater changes are brought by anthropogenic impacts (Figure 2.3). The Canyon zone is relatively steep (average slope of 0.65%) and forested, and the river corridor is geologically confined. It is mostly unaltered except for several diversion dams and Colorado Highway 14, which parallels the river. The Rural zone, stretching from the canyon mouth to Overland Trail, is on the upper piedmont which remains relatively steep (average slope of 0.55%). Here, the floodplain opens up and the river is mostly unconfined, except for a few points where it flows through water gaps in the hogbacks. Rural-land uses dominate the landscape, but some higher-density residential development is situated adjacent to the river in the Town of Laporte and diversion dams segment the river.

In the Urban zone, the river flows through Fort Collins where there is a high level of residential, commercial, and industrial development, along with many bridges and diversion dams. The river is less steep in this zone (with an average slope of 0.40%) and is naturally unconfined. However, floodplain encroachment, channelization, and artificial stabilization have confined the river through most of this zone. Below Fort Collins, the Poudre exits the piedmont to flow into the plains. Average river slope in the Plains zone is 0.27%, but there is an abrupt change from 0.35% to 0.15% at the toe of the piedmont near the Environmental Learning Center (ELC). The natural geologic channel confinements in this zone are few, and the historic valley bottom would have been at its widest here. Even though the dominant land uses on the plains are rural and industrial (mostly gravel mining), the floodplain extent is tightly confined by artificial features such as berms, roads, and bridges.

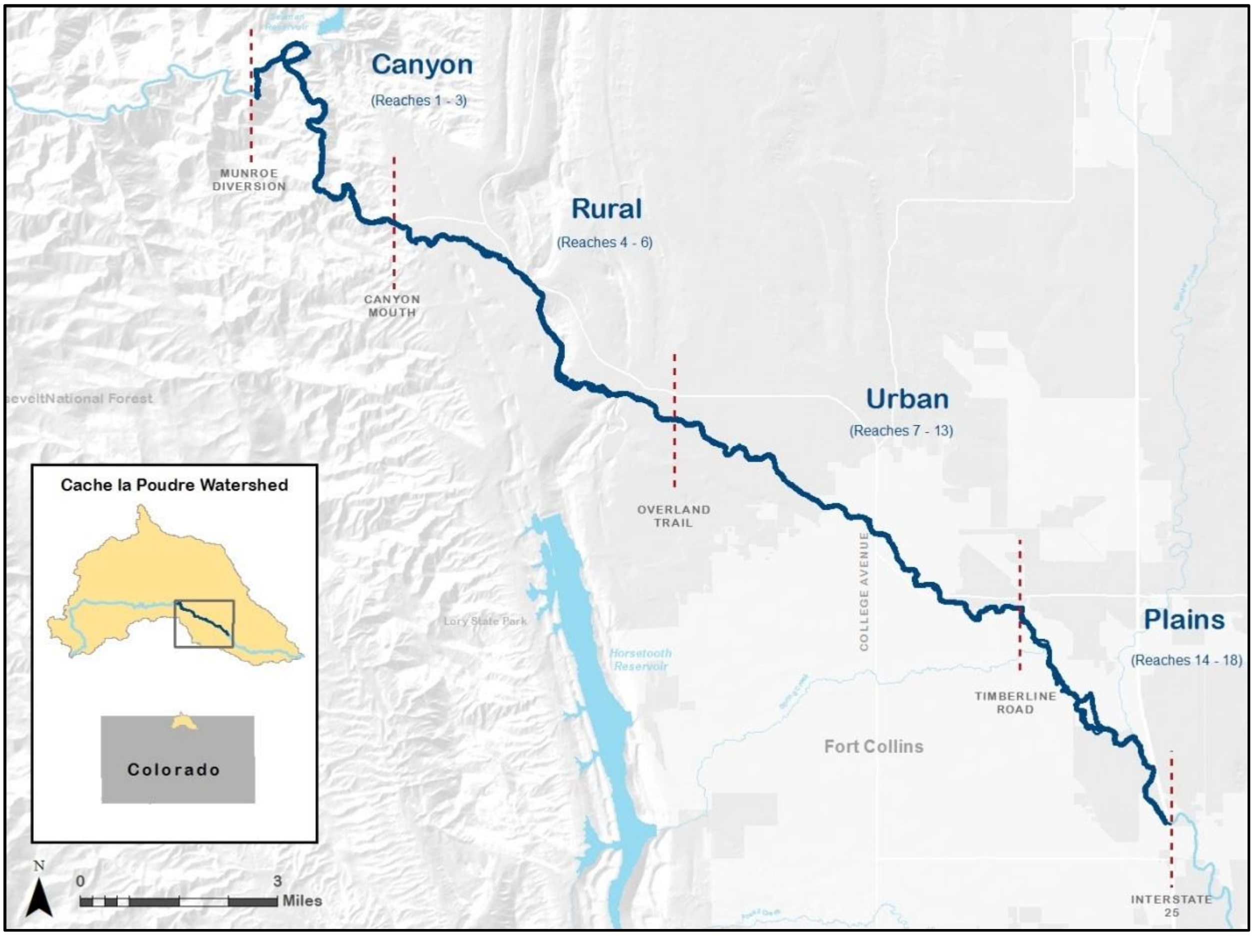


Figure 2.2: Map of the State of the Poudre River (SOPR) study area depicting the four study zones.

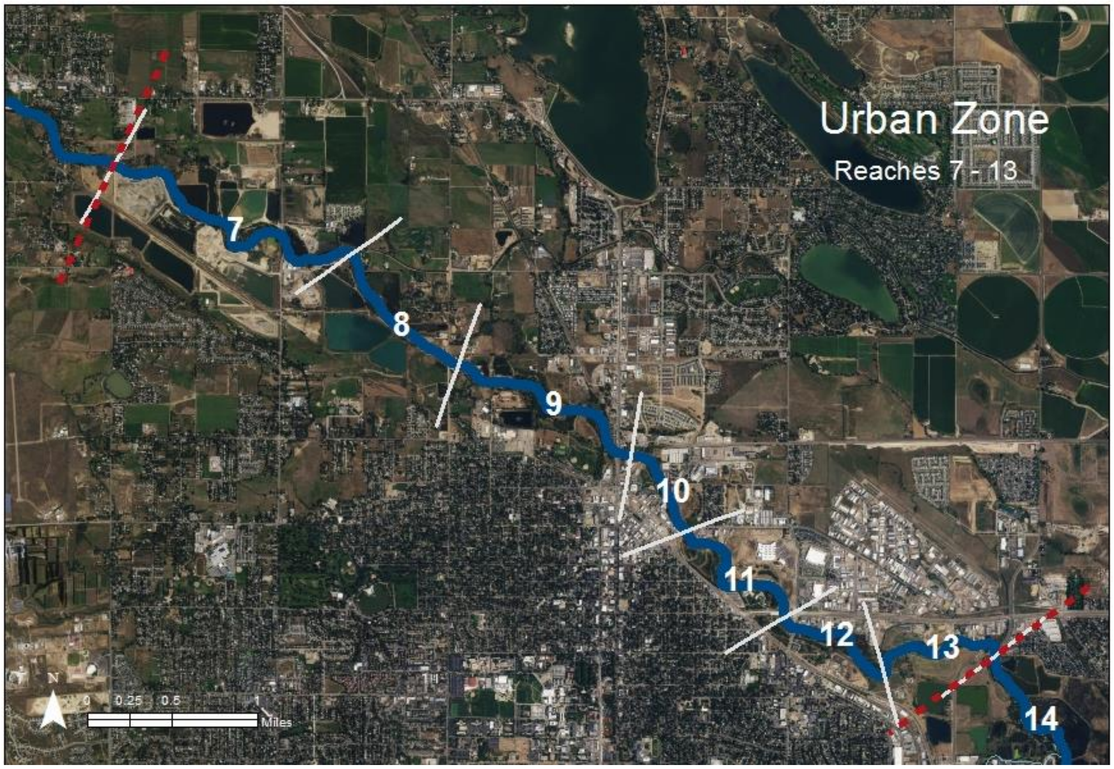
The four zones are divided into 18 reaches. Reach breaks mark important changes in river form, land use or water use (Figures 2.3 a-d). Because each sub-discipline in river science evaluates the condition of its resource at a subject-appropriate scale and using distinct approaches and data sets, all assessment results were translated to the 18 reaches during analysis and reporting. Appendix C provides further explanation of subject-specific sub-reaches and study site nomenclature established in other monitoring or research programs.

Table 2.3: A list of the landmarks used to define the upper and lower end of each of the 18 study reaches.

Location descriptions for each SOPR study reach
1. Munroe Canal Diversion to North Fork Poudre River
2. North Fork Poudre River to Poudre Valley Canal
3. Poudre Valley Canal to Greeley Diversion
4. Greeley Diversion to County Road 54
5. County Road 54 to Rist Canyon Road
6. Rist Canyon Road to just below Overland Trail*
7. Just below Overland Trail to Larimer Weld Canal
8. Larimer Weld Canal to Shields Street
9. Shields Street to College Avenue
10. College Avenue to Lincoln Street
11. Lincoln Street to Mulberry Street
12. Mulberry Street to Timnath Reservoir Inlet Canal
13. Timnath Reservoir Inlet Canal to Timberline Road
14. Timberline Road to Prospect Road
15. Prospect Road to Fossil Creek Reservoir Inlet Diversion
16. Fossil Creek Reservoir Inlet Diversion to Boxelder Creek
17. Boxelder Creek to Rail Road Bridge
18. Rail Road Bridge to Interstate-25

*The break point for this reach is at the downstream end of Butterfly Woods Natural area, which is located just downstream of Overland Trail.

Figure 2.3a and b: Each zone in the SOPR study area and their corresponding reach breaks shown on land imagery.



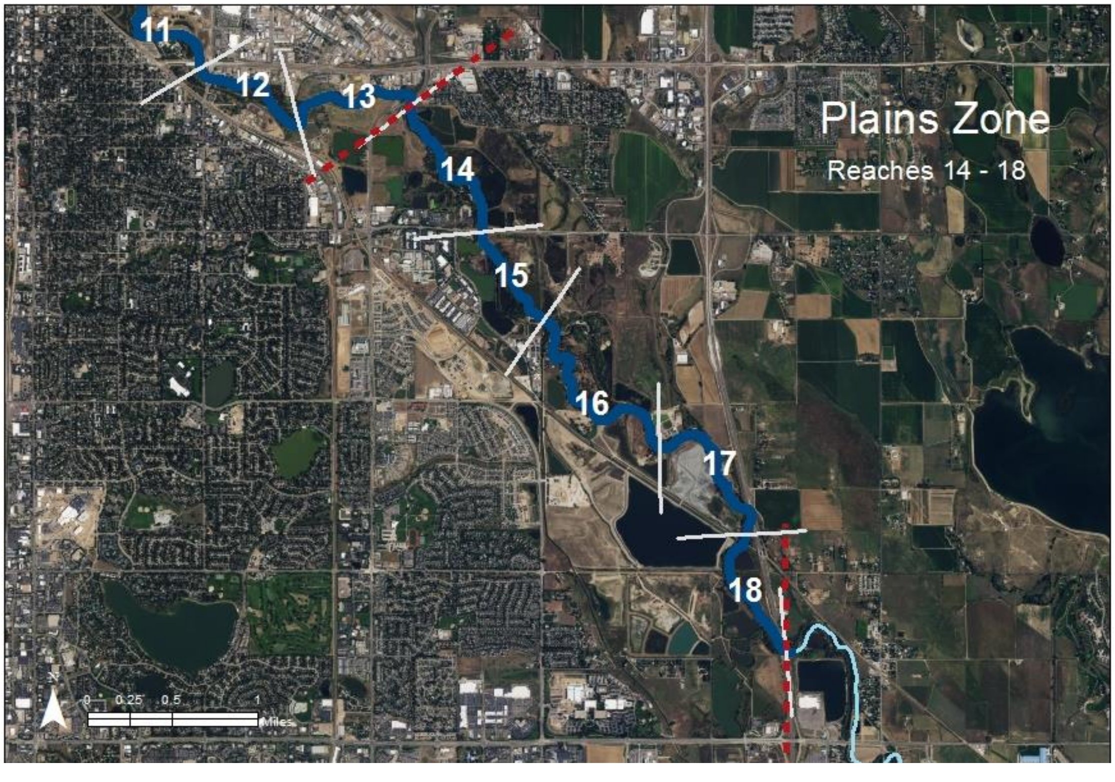
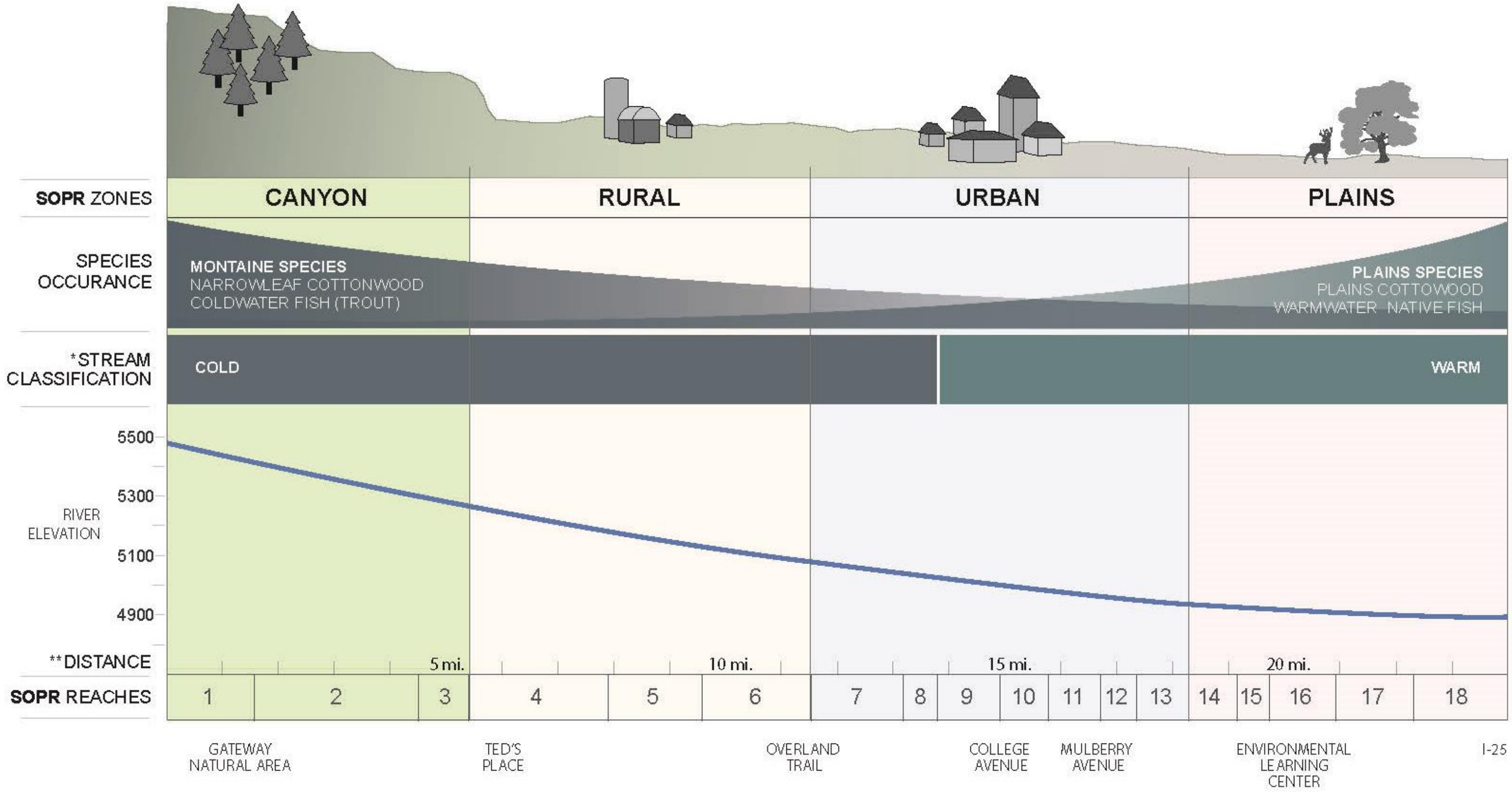


Figure 2.3c and d: Each zone in the SOPR study area and their corresponding reach breaks shown on land imagery.

Figure 2.4: Conceptual diagram illustrating the transitioning nature of the river within the study area. Landmarks are presented at the bottom of this graphic. The specific zone and reach break points are listed in Figure 2.2, 2.3 and Table 2.3.



***Stream classification refers to the aquatic life use designated by the Colorado Department of Public Health and Environment. This transition zone includes three classifications (from upstream to downstream) aquatic life cold 1, aquatic life cold 2, and aquatic life warm 1. Temperature criteria for these classifications are cold stream tier II for both aquatic life cold classifications and warm stream tier II.**

**** The distance line in this graph shows the river miles within the study area, where zero miles is at the Munroe tunnel. The 24 miles SOPR study area sits approximately in the middle of the entire Cache la Poudre river which runs for a total of 126 miles.**

2.4 Scoring process

Throughout this report, metrics and indicators are presented as numeric scores or the corresponding letter grade for ease of interpretation. At the finest scale, metric scores were assigned to each assessment unit (a reach, sub-reach, or habitat patch) based on the specific scoring guidelines. Metric scores were then combined per the procedures described in Section 2.5 to produce indicators scores. Indicator scores were then combined into a river health grade for each reach and zone using a weighted average, and finally zone grades were combined to provide an overall health grade for the Poudre within the SOPR study area (Figure 2.5).

When combining indicators to develop zone based health grades, the framework takes into account the natural hierarchy in the influence that different indicators have on river health. That is, while there are many connections within and among the indicators, hydrological and physical indicators tend to influence biological indicators more than *vice versa* (a further explanation of this can be found in the RHAF). Therefore, the framework weights each indicator based on its relative influence on river heath, to provide a more accurate portrayal of river health.

The relative contribution of each indicator to the overall health score in the SOPR assessment is:

- Flow regime – 20%
- Sediment Regime – 5%
- Water Quality – 10%
- Floodplain Connectivity – 10%
- Riparian Condition – 20%
- River Form – 10%
- Resilience – 10%
- Physical Structure – 10%
- Aquatic Life – 5%

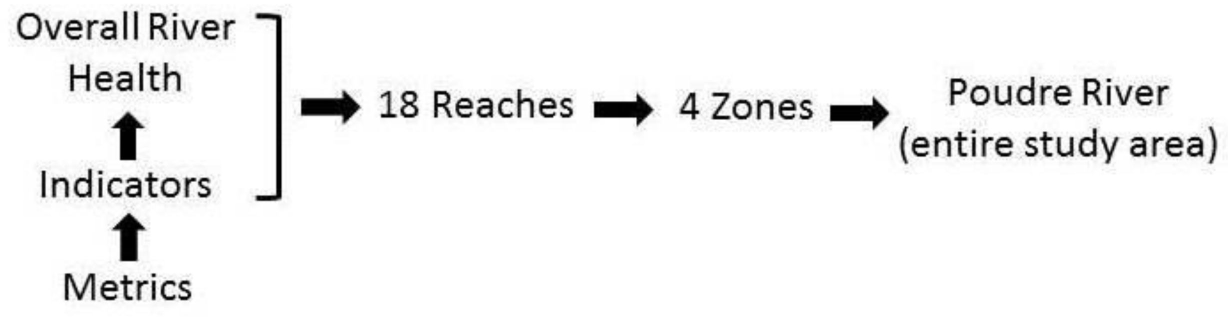


Figure 2.5 In this assessment, individual metrics are combined into indicator scores and then into holistic river health scores for the reaches, zones, and the entire Poudre River study area.

2.5 Field application of the River Health Assessment Framework

The specific methods used to grade each metric and indicator in this SOPR baseline assessment are described in this section. A combination of existing data, remote survey data, and field assessments was used to score each metric according to the revised Poudre RHAF guidelines. The complete and updated description of the grading guidelines for each metric is provided in Appendix B.

Flow regime

The flow regime indicator grade consists of three metrics: **peak flows, base flows,** and **rate of change**. These metrics were assessed using historical discharge data collected at three gages along the Poudre located at: the canyon mouth, Lincoln Street, and near the confluence with Boxelder Creek. Each gage represents a section of the river, and the SOPR employs the assumption peak flow conditions are uniform between gages. Reaches represented by each gage section were assigned a grade based on conditions measured at the gage. No attempt was made in this study to interpret impacts, such as diversions, at a finer scale within these three sections. Canyon zone reaches upstream of the gage at the canyon mouth were given the same grade as those below the canyon mouth, in the Rural zone.

As per the RHAF guidelines, a quantitative approach using sub-metrics for peak *three-day magnitude* and *frequency* was used in scoring peak flows. The grading guidelines were expanded upon from the RHAF in order to provide "+" and "-" modifiers for grades. This information is included in the grading guidelines for flows in Appendix A.

Trends in base flow magnitude, duration, and timing observed on plotted hydrographs for each gage were considered when scoring the **base flow** metric. To score the base flow metric, mean and minimum winter daily average discharge values were calculated for the period of record at each gage and compared to numerical standards. These calculations were then viewed in light of the other qualitative assessment scoring criteria to produce the final grade. The flow regime indicator grade was calculated using a weighted average of the three metric scores with 50% weight assigned to the peak flow metric and 25% apiece to the base flow and rate of change metrics.

Sediment regime

The sediment regime indicator has three metrics. The **land erosion** metric was graded using evidence for land disturbance that is visible on current aerial imagery, including: road density, devegetated slopes, clear-cuts, and human-caused mass erosion. The greatest land disturbance in the watershed is the burn scar left behind by recent wildfires. GIS layers outlining the burn scars by degree of intensity were used to calculate the percentage of burned area in the contributing watershed for each reach as part of the scoring for this metric. Land erosion metric scores in the Canyon and Rural zones are, therefore, closely tied to the proportion of burned area in the contributing watershed. In the Urban and Plains zones, sediment from other land uses and outfalls becomes more important. The combined influences of these sources were evaluated qualitatively during rapid field assessment.

A grade for **channel erosion** was applied to each of 99 river sub-reaches using evidence of channel erosion on current aerial imagery, and knowledge gained through field-based observations which included on foot survey of most of the river in the project area in Fort Collins. Remotely assigned grades were re-evaluated during field surveys (see the river form, resilience, and physical structure sections, below). Sub-reach scores were weight-averaged by length to calculate grades for the respective reaches.

In-line dams affect sediment **continuity**, and the proportion of the contributing watershed from which sediment is retained was a primary basis for grading. Additional impacts to sediment continuity by smaller in-line diversion dams and transport limitations caused by flow regime and river form impairment were considered secondarily. Evidence of sediment-continuity impairment from these secondary sources was evaluated during field surveys.

The sediment regime indicator score was calculated as straight average of the three metrics.

Water quality

The water quality indicator grade was determined by evaluating data for four metrics **temperature**, **nutrients**, **pH**, and **dissolved oxygen** at several monitoring sites situated along the Poudre River (Appendix C). Data were collected in 2015 from seven monitoring sites associated with the Upper Cache la Poudre (CLP) Collaborative Water Quality Monitoring Program and the Lower CLP Water Quality Monitoring Program (Figure 2.6). Water quality data collected in 2015 were used here because the 2016 were not yet available at the time of the SOPR assessment.

Figure 2.6: At left, Jill Oropeza, Water Quality Services Manager analyzes water quality in the upper Poudre River. To the right, clear water, clean cobbles and low levels of undesirable algae are signs of good water quality.

The Poudre River was divided into eight reaches for the water quality assessment to evaluate impacts of potential stressor on water quality through the project extent. Reach breaks were established based on contributions from major tributaries and reservoirs, changes in Colorado Department of Public Health and Environment (CDPHE) Stream Segment and Classification, known dischargers to the Poudre River, and the location of water quality monitoring sites (Appendix E). Water quality data collected at monitoring sites located within a specified reach were used to grade the entire reach. In the one circumstance where a water quality monitoring site was not located within the reach (WQ3), data collected from the nearest downstream site (PLNC) were used to grade the upstream reach (WQ3). The lowest elevation water quality reach (WQ8) was downstream of the end of the SOPR study area, but this reach was included in the grading assessment for water quality because the City's water treatment operations extend downstream of I-25.

Numeric grades for the eight water quality reaches were determined by evaluating metric data compared to updated RHAF grading guidelines for water quality (Appendix E). The overall water quality indicator grade was calculated using a formula that equally weights the average of the metric scores and the lowest of the metric scores [*water quality = 50% (average of metric grades) + 50% (minimum metric grade)*]. This method recognizes the cumulative effects of multiple water quality factors and also that one factor may serve as a limit to water quality. Water quality reach grades were then translated to the 18 SOPR reaches for consistency with other indicators and to be included in the calculation of the overall river health grade.

Floodplain connectivity

The floodplain connectivity indicator has only a single metric, **floodplain extent.** This is a measure of the width of the riparian zone that is flooded on a regular basis and which supports riparian species and processes (Figure 2.7). The extent of the five-year return interval floodplain was mapped using a Hydraulic Engineering Center – River Analysis System (HEC-RAS) model provided by the City of Fort Collins. Digital terrain data for the model came from a 2014 LiDAR survey and additional channel cross-section data from land surveys (King Surveyors, Spring 2013 and Spring 2014). The model covered the river reach from just upstream of Shields Street to just downstream of I-25. Channel widths were manually measured using aerial imagery at each modeled cross-section and then subtracted from the modeled water surface width to get the resulting floodplain width. For reaches upstream of where HEC-RAS model results were available, current aerial imagery was used to estimate the width of the 5-year floodplain. The degree of floodplain encroachment was estimated by evaluating evidence of land-use change and comparison to similar reaches for which modeled results are available.

Figure 2.7: A riparian area with good floodplain connectivity as demonstrated by the seasonal flooding that occurs and the healthy riparian forest sustained by floodwaters.

Riparian condition

The lateral extent of the SOPR riparian zone was defined as the edge of the natural floodplain or 100 meters from the river bank, whichever was narrower. In the SOPR riparian zone 3 metrics were assessed to develop riparian condition indicator grades. For the **vegetation structure** metric, the complex mosaic in the riparian zone was mapped by delineating patches (polygons) and classifying them by land cover using ten categories: native montane mesic, canopy forest, sub-canopy forest, scrub-shrub, herbaceous, emergent wetland, urban, developed, bare ground, or lentic open water. Patches were also classified by land use type, development level, and floodplain position using 2015 aerial imagery. City of Fort Collins Natural Areas mapping, National Wetland Inventory maps, and imagery from other years were also viewed to provide additional perspective. Mapped and classified patches were then evaluated to score the riparian condition metrics.

A two-level approach was used for evaluating the vegetation structure metric. The Level 1 approach was mainly a desktop exercise that relied on remote data such as aerial imagery and limited ground truthing. Field observations were incorporated at level 2. Assessment level was dictated by land cover and access. For instance, level 1 is sufficient for evaluating vegetation structure on urban, developed, bare ground, and lentic (non-flowing) open water land cover types. Patches of simple herbaceous vegetation such as turf and lawns are also easily evaluated remotely, but field assessments are needed to suitably evaluate sites with more complex natural vegetation. As many complex vegetation patches as practicable were evaluated using level 2 methods, including 100 of the 218 canopy forest patches, 41 of 88 sub-canopy patches, 22 of 78 scrub-shrub patches, and 12 of 36 emergent wetland patches. The remaining patches in these classes were evaluated at level 1, using field evaluations to inform grading by comparing them with similar patches evaluated in the field.

Level 1 grading involved assigning grades based on evidence of vegetation structure visible in aerial imagery, and then downwardly adjusting the grade a little more than half a letter grade (7%) when patches were artificially isolated from the river (*e.g.*, when behind berms). For level 2 grading, nine sub-metrics were evaluated in the field:

- Vertical complexity – number of vegetation layers (herbaceous, shrub, sub-canopy, canopy)
- Canopy species – proportion of native species in the canopy layer
- Sub-canopy species – proportion of native species in the sub-canopy layer
- Shrub layer – abundance of shrubs
- Problem herbaceous species – abundance of non-native herbaceous species that alter function
- Problem woody species – abundance of non-native woody species that alter function
- Patchiness and interspersion – structural diversity by area, rated: none, low, moderate, high
- Native woody species regeneration – number of native, woody-species age classes
- Floodplain position – position on the floodplain, based on hydraulic connectivity to the river (riverine, depressional, or terrestrial)

Full description of the grading criteria for each of the riparian sub-metrics can be found in Appendix D.

Figure 2.8: Riparian forest with moderate structural diversity (left). Recently deposited plains cottonwood seeds on bare moist soil, shown in the photograph at right illustrate the ideal conditions for successful cottonwood germination.

The **habitat connectivity** metric was evaluated using aerial imagery to determine the amount of continuous riparian habitat remaining within the SOPR riparian corridor. Transverse breaks in habitat caused by development and infrastructure, such as roads, were then considered as possible migration and dispersal barriers. Where barriers are present, grades were lowered accordingly to reflect the degree of habitat isolation. The **contributing area** metric was also evaluated using aerial imagery to characterize land use in the 200-meter buffer area surrounding the delineated riparian zone.

The riparian condition indicator grade was calculated using a weighted average of the three metric scores with 80% weight on the vegetation metric and 10% each on the habitat connectivity and contributing area metrics.

River form

River form was rated using the average score of three metrics that describe key aspects of river shape: **planform, dimension,** and **profile**. All three of these metrics were graded at the sub-reach scale during field surveys by fluvial geomorphologists with experience on the Poudre and other Front Range rivers. 22.6 miles of the 23.9-mile study area was assessed in the field. The remaining 1.3 miles (on private land with no access) were scored using remote data such as aerial imagery. Scores reflect the degree of departure from natural reference river form for the respective reach using evidence of anthropogenic impacts, or stressors. Reach scores were then calculated as the average of the component sub-reach's scores, weighted by length.

Planform was assessed using aerial imagery and site observations for changes to river branching and braiding patterns, sinuosity, belt width, meander length and width, amplitude, and bend radius of curvature. Direct evidence of planform impairment was documented during field visits by noting areas of floodplain encroachment, channelization, realignment, and bank or channel armoring.

The **dimension** metric evaluates cross-sectional shape and size of the river channels, its associated floodplain, and flood-prone area. It is evaluated using three sub-metrics:

- *Entrenchment* – Degree to which the river channel is artificially confined or isolated from the floodplain. It is scored by evaluating criteria for the width of flood-prone area and the ratio of bank height to the height of water surface at bankfull discharge, or "bank height ratio". Entrenchment was not used to evaluate dimension in the Canyon zone since the river in that zone is naturally entrenched.
- *Width-depth ratio* - Degree to which the channel top width is has become wider or narrower relative to mean depth at bankfull discharge.

Profile describes a river's bed grade, or longitudinal slope. The metric is evaluated by documenting changes to overall slope, usually due to altered planform, and to localized changes caused by dams, grade control structures, or geomorphic responses such as aggradation zones or head-cuts.

Resilience

The resilience indicator grade is an average of two metrics: dynamic equilibrium and recovery potential. Both metrics were first remotely evaluated using historical aerial photos to document stability trends, changes to river form, lateral migration, avulsions, and erosion. Field observations were then made during site visits to observe stressors and direct signs of instability. For the **dynamic equilibrium** metric, stressors such as altered peak flow and sediment regimes, channel evolution stage, changes to stream form, and direct impacts such as channel and bank hardening were all taken into account. Signs of channel instability observable during field surveys included excess deposition, scour, or bank erosion, pool filling, unnatural bar development, and severely over-widened or entrenched channel form.

Recovery potential was graded considering the apparent potential for the reach to recover characteristic functioning after disturbance, while also considering risks to public safety and infrastructure damage. Two general criteria guided grading:

- *Channel migration zone* is the width of the corridor in which the river can freely migrate, unconstrained by artificial structures and without causing significant infrastructure damage. The width of the existing channel migration zone was compared to the historical condition, using evidence of past fluvial features and human impacts that restrict lateral movement of the river.

- *Reliance on artificial stabilization* measures was rated as the degree to which channel stability depends on artificial stabilization, such as engineered structures or routine maintenance.

Physical structure

The physical structure indicator grade is the average of two metrics that consider different scales of river structural diversity (Figure 2.9). The **coarse-scale** and **fine-scale** physical structure metrics were both graded based on field observations of the 22.6 river miles that were visited. Grades for the reaches on the 1.3 miles that were not observed in the field were extrapolated from similar reaches, guided by aerial imagery. Coarse-scale physical structure grades were based on qualitative estimation of the diversity of water depth/velocity combinations, topographic complexity of the bed and banks, and physical structure of the reach compared to the natural reference (Figure 2.9). Fine-scale structure grades relied heavily on field observations of interstitial space availability, bed armoring, embeddedness, and algae in riffles (Figure 2.10).

Figure 2.9a-d: Examples of different coarse-scale habitat conditions (clockwise from top left) include a) steeper plane-bed channel in the Canyon zone with large boulders providing diverse habitat, b) pool-riffle sequencing with large-wood helping create pool scour, c) homogenous run habitat lacking diverse coarse structure especially pool habitat, and d) homogenous glide habitat created from backwater conditions at the diversion dam downstream.

Figure 2.10: Field observations of interstitial space availability, bed armoring, embeddedness, and algae in riffles helped inform the fine-scale metric grades.

Aquatic life

The **aquatic insects** metric was evaluated using aquatic insects community data from samples taken from 13 sites in 2015 and 2016 (Appendix C). Results for six sub-metrics were used to calculate a single index score using the CDPHE Multi-Metric Index (MMI) tool, and the index values were converted to aquatic insect metric grades for each sampling site using RHAF guidelines. According to the MMI tool, a single index score (the MMI) was calculated for each sample as the average index from six sub-metrics. Aquatic insect metric grades were assigned based on the grading criteria in the Poudre RHAF. All reaches represented by a station were scored the same. The six sub-metrics used in calculating the MMI were selected based on their known sensitivity to a variety of types of human induced stressors in this region:

- EP taxa – a measure of community richness based on the number of Ephemeroptera and Plecoptera (mayfly and stonefly) taxa present
- Chironomidae – relative abundance of the family Chironomidae (non-biting midges)
- "Sensitive plains" families – percentage of certain sensitive taxa identified by CDPHE to be common on healthy Colorado plains' rivers
- Predator/Shredder taxa – relative abundance of taxa in the predator and shredder feeding groups
- Clinger taxa – relative abundance of taxa classified as clingers
- Non-insect taxa – relative abundance of non-insect taxa

The **aquatic habitat connectivity** metric was graded based on the distance between fish passage barriers, which are primarily diversion dams along the Poudre River. A structure is considered a barrier if it prevents fish from moving past (up) it for the majority of the year. All structures are passable in the downstream direction during the highest flows but currents under these flow conditions are too swift for upstream movement.

The length of the habitat connectivity segment between successive barriers was measured and scores were assigned. The aquatic habitat connectivity segment scores were overlaid on the 18-reach scale and then weight-averaged to determine final scores for each reach. The score for the most downstream reach is based on the distance to the Greeley Canal #2 diversion structure, which is the next significant barrier downstream, even though it is outside the study area.

Five stations were sampled in 2015 between College Avenue and I-25 by either CPW or the Colorado State University Larval Fish Laboratory (CSU-LFL) to assess **native fish** species composition (Appendix C). Seine nets and electrofishing methods were used at each station to capture live fish and determine the presence or absence of multiple life stages of native fish species (Figure 2.11). Metric grades were assigned based on two sub-metrics:

- *Number of native species* – Number of native fish species captured in sample efforts
- *Number of species with multiple life stages* – Number of species for which fish of multiple life stages were captured

Only reaches with 2015 sample stations were graded.

Figure 2.11: Colorado Parks and Wildlife staff electrofishing in a plains stream.

Trout are expected on the Poudre upstream from approximately the mid-point of the Urban zone. The **trout** metric was evaluated on these reaches by Colorado Parks and Wildlife (CPW) biologists who used two-pass electrofishing sample methods to monitor trout populations at several stations along the Poudre River annually. One station is at Gateway Park on Reach 1 (Munroe Diversion to North Fork) in the Canyon zone. Another is at Lee Martinez Park on Reach 9 (Shields to College) in the Urban zone. Results from these two stations, sampled in 2016, were used to grade the trout metric based on six sub-metrics:

- *Age classes* – Number of age classes of brown trout
- *Recruitment* – Number of Age-0 brown trout, assessed as low, medium, or high
- *Recreation potential* – Number of quality-size (> 9 inches) brown trout, assessed as low, medium, or high
- *Relative weight* – Average relative weight for stock-sized (> 6 inches) brown trout. Relative weight – the ratio of actual fish weight to the weight of a healthy fish of the same length – is a measure of fish health
- *Biomass*– Biomass of stock-size (> 6 inches) brown trout, in pounds per acre.
- *Population number* – Number of stock-size brown trout per mile of stream, assessed as low, medium, or high

The aquatic life indicator grade was calculated using a weighted average with 70% weight on the aquatic insects metric and 30% on the habitat connectivity metric. Trout and native fish scores are not included in scoring the indicator aquatic life since fish data for this assessment year was not available for the Rural zone and broad extrapolation of site specific data to the zone as a whole would have increased inconsistencies. Trout populations and native fish community structure mainly represent ecosystem response variables, rather than drivers of overall river health. Therefore, for this year's assessment fish grades are only provided where data was directly available.

3 Ecological stressors

The Poudre River, like all ecosystems, developed and evolved naturally in step with the geologic, climatic, and biological processes at play in the environment. The river's natural condition was one which defines ecological health – the river ecosystem was functioning in a dynamic equilibrium with climate and geology. The system was ever changing and often profoundly disrupted by shifts in the environment and extreme events. But the river's natural condition was resilient, and it would reshape itself based on the new constraints of the climate and landscape. Ecological health can be influenced—and functional capacity weakened—by human impacts. Stressors are the human impacts— past or present—that impair river health, resulting in decreased functioning if left unmanaged. Some forms of natural disturbance can be exacerbated by human activity and turned into stressors on the river ecosystem. One example is a wildfire that is either started because of human activity or exacerbated because of previous forest management that suppressed fires. The important ecological stressors affecting Poudre River health are described in this chapter (Table 3.1).

Table 3.1: Ecological stressors affecting Poudre River health.

	Stressors	Explanation
Watershed and contributing area	Diversions (withdrawals)	Exported water (withdrawals)
	Transbasin diversion (augmentation)	Imported out-of-basin water (augmentation)
	Large dams/reservoirs	Large in-line dams and reservoirs on the Poudre or major tributaries
	Wildfire/burn scars	Wildfire burn scars in watershed
	Channel erosion (in watershed)	Sediment supply from eroding channels (includes artificially low supply from stabilized channels)
	Impervious surfaces/urban stormwater runoff	Flows from impervious surfaces, urban drainage (including any pollutants)
	Irrigation runoff/return flows	Return flows (including any pollutants)
	Wastewater effluent	Effluent from treatment plants or facilities
River and riparian zone	Development	Riparian land use: commercial/industrial, infrastructure, transportation corridor, residential
	Rural/agricultural land use	Riparian land use: rural, pasture, light agriculture, intensive agriculture
	Open space and parks	Riparian land use: naturalized open space, parks, disturbed open land
	Gravel pit/ponds	Riparian land use: gravel pits, ponds
	Road/bridge	Roads and bridges in riparian and channel area
	Berms/channelization	Berms and channelized river segments
	Bank/channel armor	River segments stabilized with engineered structures, armored banks (*e.g.* rip-rap)
	Channel structures (dams/weirs)	Diversion structures, dams, weirs
	Woody material recruitment/removal	Lack of woody material recruitment (due to stabilization or riparian degradation) or removal
	Exotic plant species/weeds	Exotic plants in riparian area

3.1 Watershed and contributing area stressors

Stressors occur in the watershed or surroundings, and they are "inherited" by a river reach. Stressors in the watershed caused by land-use changes or other impacts primarily affect flow regime, sediment regime, water quality, and aquatic life, but river health may also be indirectly impaired in other reaches. For example, diversions in the headwaters that impair flow by truncating peak flows may also affect floodplain connectivity by reducing the return interval of overbank events far downstream. Similarly, the water quality of a reach may be impaired due to chemical impacts that occur far upstream. From the perspective of the City of Fort Collins, the critical difference between stressors occurring on properties under City management and those occurring elsewhere in the watershed is that the former may be addressable through changes in management practices, whereas the latter must largely be accepted as an inherited condition or improvements must be pursued by engaging in collaborative efforts.

Diversions *(flow withdrawals)*

There are numerous diversion points on the Poudre River upstream of I-25 where water is drawn out of the river for agricultural, industrial, and municipal uses. The major diversions were recently summarized for the City of Fort Collins Natural Areas Department (Figure 3.1) using records to quantify capacity and average annual volume. Fort Collins Utilities diverts roughly one-half of its water supplies from the Poudre River. Diversions occur at Gateway Park just upstream from the North Fork confluence. Other operations, such as exchanges and gravel pit operations, affect flows within the Urban and Plains Zones.

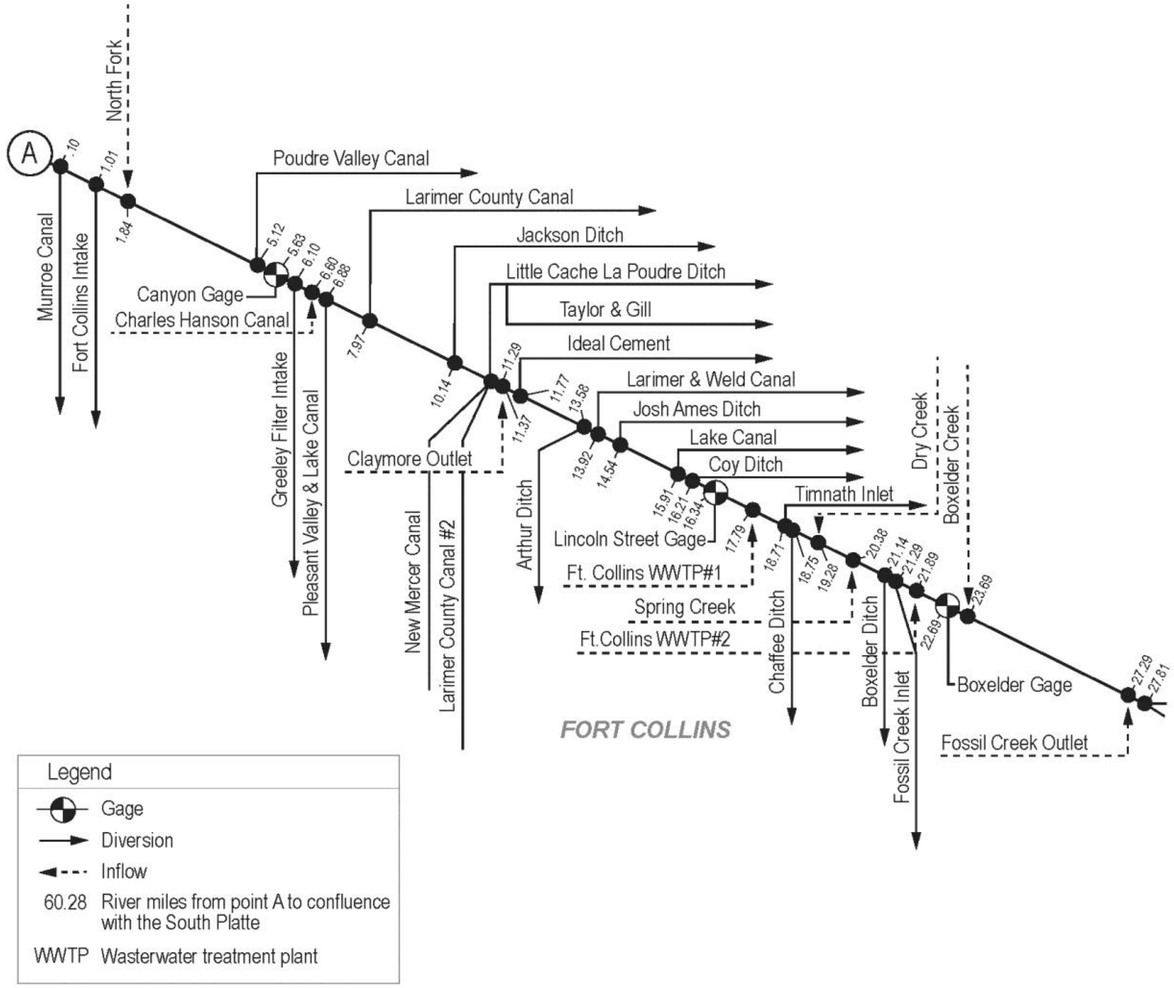


Figure 3.1: Line diagram of diversions and inputs on the Poudre, including the distance between each structure in the SOPR study area. This diagram illustrates how fragmented aquatic habitat is in the SOPR study area (provided by Northern Colorado Water Conservancy District, 1996).

Diversions directly affect components of flow regime, including peak flow, base flow, and rate of change. Peak flows can be truncated by diversions made during spring and summer, while base flows are commonly decreased by diversions during fall and winter or during drought. Rates of flow change can be impacted when diversions are opened and closed, especially during periods of low flow. The average rate and annual volume of water diverted during winter months (November through March) were also calculated for each diversion point. An average of about 38,000 acre-feet per year is diverted from the Poudre in or above the study area during winter months, and wintertime dry-ups sometimes leave the river with little to no flow (Table 3.2).

Flow withdrawals can also affect water quality and physical structure. Excessively low flows elevate radiant heating and cooling, making the river vulnerable to extreme temperatures with increased highs in summer, decreased lows in winter, and greater diurnal fluctuation. Low flows may also exacerbate chemically-related water quality issues such as nutrient loading and suppressed dissolved oxygen content by lessening the effectiveness of dilution, altering biogeochemical processes, and limiting the effectiveness of turbulence and mixing. The amount, availability, and diversity of physical structure (*i.e.*, riverbed habitat available to fish), may be severely limited during low flow periods, which can directly affect aquatic species survival especially during critical late summer, fall, and winter flow periods. Low flows are more of a stressor in some reaches during late summer and fall and some reaches are particularly affected by wintertime diversions (Table 3.3).

Table 3.2: Annual average volume, wintertime average volume, and wintertime average discharge values for the indicated period of record (Bishop-Brogdan Associates, 2015).

Poudre River Wintertime Diversion summary				
Diversion	Wintertime average diversion (Nov-Mar)			
	AF	CFS	Frequency	Period
Worster/Eaton Reservoir	420	1.4	fairly constant	1997-2013
Halligan Reservoir	3,900	13.0	fairly constant	1997-2013
North Poudre Canal	3,500	13.0	each year since 2002	1997-2013
Milton Seaman Reservoir	570	1.9	sparse (since 2001)	1997-2013
Long Draw Reservoir	690	2.3	fairly constant	1997-2013
Peterson Lake Reservoir	N/A	N/A	sparse	1997-2013
Joe Wright Reservoir	540	1.8	fairly constant	1997-2013
Chambers Lake Reservoir	1,650	5.5	fairly constant	1997-2013
Barnes Meadows Reservoir	30	0.1	sparse	1997-2013
Munroe Canal	210	0.7	some since 2009	1997-2013
Fort Collins Pipeline	1,900	13.0	fairly constant	1997-2013
Poudre Valley Canal	270	0.9	sparse	1997-2013
Greeley Filters Pipeline	6,225	20.8	almost always	1997-2012
Watson Lake Diversion	25	0.1	constant	1997-2012
Little Cache Diversion	1,150	3.8	fairly constant	1997-2012
Larimer and Weld Canal	3,330	11.0	fairly constant	1997-2012
Timnath Reservoir Inlet	5,010	16.7	constant	1997-2012
Fossil Creek Reservoir Inlet	6,190	20.6	constant	1997-2012
Total	**37,980**	**126.6**		

Table 3.3: Base flow statistics for points just downstream from five of the diversion points on the Poudre for the period 1970 to 2010. (Bishop-Brogdan Associates, 2015).

Base Flow Criterion	Greeley Filters Pipeline Diversion	Little Cache Diversion	Larimer Weld Canal Diversion	Timnath Reservoir Inlet Diversion	Fossil Creek Reservoir Inlet Diversion
Average number of days per year with continuous flow below 35 CFS	102	104	135	136	178
Average percent of winter days with flow below 35 CFS	77%	74%	75%	74%	79%
Average number of days per year with continuous flow below 10 CFS	28	31	75	70	111
Average percent of winter days with flow below 10 CFS	38%	27%	51%	52%	65%
Average number of days per year with continuous no flow	3	9	12	16	24
Average percent of winter days with no flow	6%	6%	19%	17%	23%

Transbasin diversion *(flow augmentation)*

At the higher elevations of the Upper Poudre Watershed, transbasin diversions import water to the Poudre River from other drainages through the Wilson Supply Ditch, Laramie-Poudre Tunnel, Grand River Ditch, and Michigan Ditch. Colorado-Big Thompson water is delivered to the Poudre through the Hansen Supply Canal via Horsetooth Reservoir. Flow augmentation via transbasin releases can have opposite effects of diversions. Releases timed with natural runoff or storm flow peaks can increase peak flow magnitude or duration, and releases during winter or other periods of low flow can supplement naturally low discharge, thereby offsetting some of the impact of diversions. Transbasin diversion releases introduce another mechanism by which flow rates can be artificially and rapidly changed and they can also impact river water quality depending on how water quality differs between the Poudre and the imported water.

Large dams/reservoirs

There are multiple reservoirs within the Upper Poudre Watershed and two large dams on the North Fork that impact the flow and sediment regime along the Poudre River. Halligan and Seaman Reservoirs are both created by large in-channel dams that regulate flow regime and cut off sediment supply to the Poudre mainstem downstream. The effects on base flow vary depending when calls on water rights are made by downstream users. However, reservoir management has the potential for exacerbating low-flow impairment and altering the rate of flow change. Reservoirs also effectively trap the vast majority of the natural and anthropogenic supply of bedload and suspended sediment, delivering mostly sediment-free discharge downstream which can exacerbate channel and bank erosion.

Other potential impacts from large dams and reservoirs include changes in water quality. Because reservoirs expose large surface areas to the sun, deep reservoirs can become thermally stratified during the summer months, resulting in warmer surface waters and colder bottom temperatures. Depending on whether reservoir water is released via a surface spillway or a bottom outlet, stream temperatures may be warmed or cooled accordingly. In this way, dams can impact the natural temperature regime of downstream receiving waters. Seasonal thermal stratification in reservoirs can also result in oxygen depletion of the bottom waters. Under these low oxygen conditions, biological processes mobilize nutrients and metals bound to bottom sediments, which can result in seasonal spikes in dissolved nutrient and metals concentrations in waters released from reservoirs. Dams are also a clear example of an extreme barrier to passage of fish and other aquatic organisms.

Wildfire *(burn scars)*

Recent wildfires in the Poudre watershed left burn scars with decreased forest cover and exposed soils that are more susceptible to runoff and erosion and deposited large amounts of ash and fine sediment into the river (Figure 3.2, 3.3). Until the vegetation sufficiently recovers, the burn scars will have a significant impact on sediment regime (land erosion) and flow regime (peak flows and rate of change). Wildfire is a natural part of the geological and ecological setting within which the Poudre River evolved. Nevertheless, decades of fire suppression in the watershed have altered the frequency, magnitude, and distribution of fires, thereby increasing tributaries.

Figure 3.2: Post fire erosion creating turbid waters.

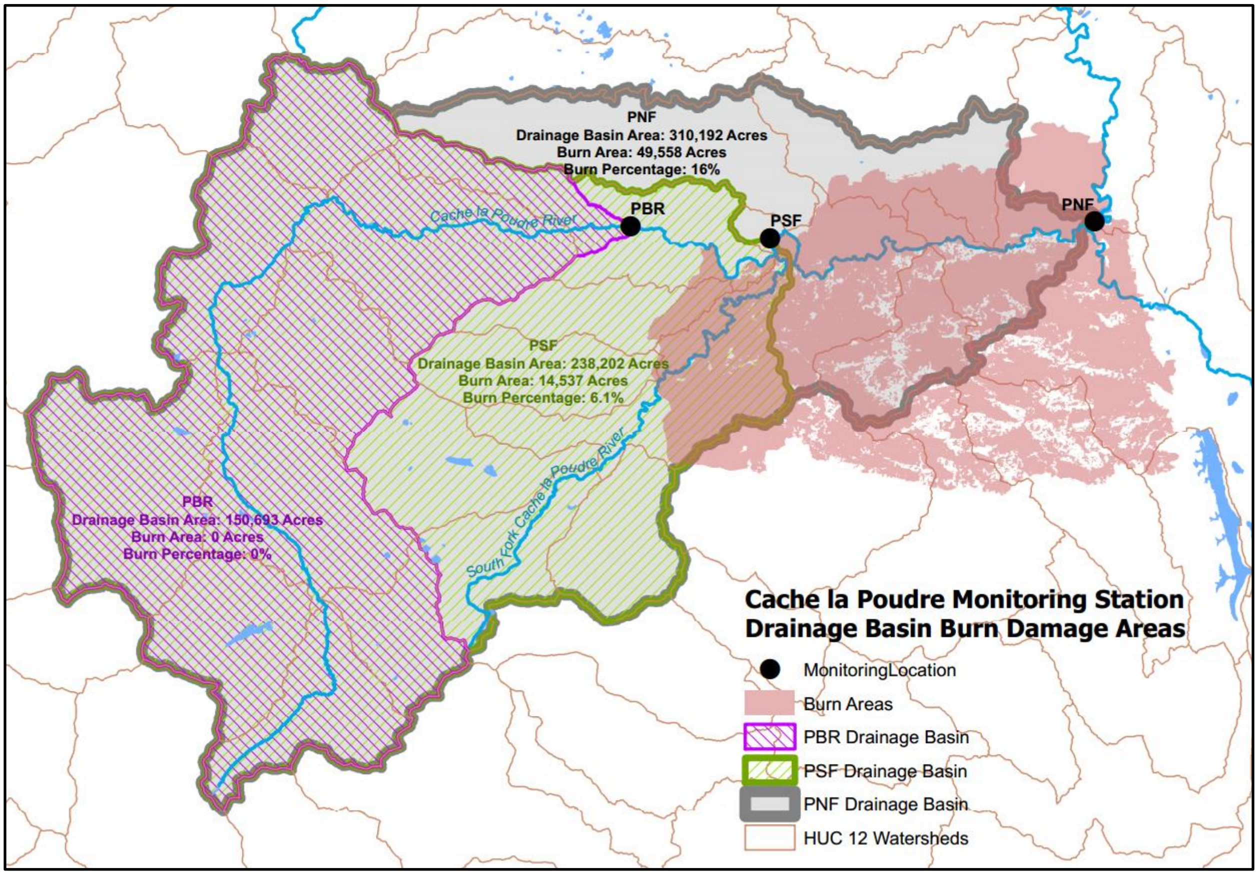


Figure 3.3: Percentage of burned area for watersheds at different points on the river (From Hohner et. al., 2016)

Channel erosion

The river is in a state of equilibrium when the sediment supply and transport capacity are in balance. Changes to land use, hydrology, or the river itself can shift this balance causing the channel to incise, aggrade, or widen as it adjusts towards a new dynamic equilibrium. Channel erosion is a natural process that allows the river to achieve this new dynamic equilibrium, resulting in the release of sediment. However, channel erosion is not always acceptable in a given location, and artificial measures such as riprap and grade control structures used to stop channel erosion are common on the Poudre and its tributaries. Artificially-stabilized river and stream sections deliver less sediment downstream, except during extreme events.

Irrigation runoff and return flows

Return flows and runoff from irrigated lands recharge flows in the river and often introduce non-point-source pollutants—particularly nutrients—which come from decaying organic material and fertilizer. Return flows offset depletions since they represent the return of diverted water back to the river, but less water is returned than was diverted because of consumptive losses, and that water is returned to a point downstream of the diversion, leaving the upstream reach dewatered.

Treated wastewater effluent

Treated wastewater effluent enters the Poudre River in three locations within the study area. Additionally, the outflow from Fossil Creek Reservoir discharges a mix of river water, wastewater from two water treatment facilities, and localized stormwater runoff into the Poudre just downstream of the study area (this site is discussed in Section 4). Treated wastewater effluent discharges are permitted by the State of Colorado and must meet quality standards designed to protect designated uses, such as aquatic life. However, despite the use of advanced technologies for nutrient removal and regulated quality standards, wastewater effluent water is typically warmer and higher in nutrient concentrations than the ambient river water, and as such, represents a potential stressor on river health. Its impact, however, depends on the time of year, streamflow, and the proportional volume of effluent in the river.

Because nutrients and temperature typically exert strong influences over productivity in local streams, excessive nutrient and thermal loads have the potential to increase algae growth and drive changes in community composition of both algae and aquatic macroinvertebrates, as well as dissolved oxygen content. Furthermore, native fish have specific temperature tolerance ranges, beyond which their ability to survive and reproduce may be impacted.

3.2 River and riparian zone stressors

Development

All commercial, industrial, infrastructure, transportation, and residential land uses in the riparian zone may be considered stressors (Figure 3.4). Commercial/industrial land uses are mainly retail and manufacturing facilities that introduce a substantial amount of artificial roof, impervious surface, bare ground, or open water cover types to the riparian zone. Infrastructure areas contain the structures, systems, or facilities that serve the public interest. Roads and railways were mapped as transportation corridors, and paved paths were considered part of the transportation corridor when they were associated with a road. Residential development is typified by suburban moderate-density housing. Residences in the riparian zone are relatively few, with most being single-family units with manicured/landscaped lots or lawns. Some high-density housing units are present in the Urban zone. These land uses are considered direct impacts to the riparian condition, affecting vegetation structure, habitat connectivity, and contributing area. They also severely limit active floodplain function since they need to be protected via channelization, berms, and fill.

Figure 3.4: Development in the historical riparian area is a stressor on reaches in the Urban and Plains zones.

Rural and agricultural land use

Ten percent of the riparian zone was mapped as “rural or agricultural” (Figure 3.5). Rural development areas are still largely vegetated, but vegetation cover is often dominated by disturbance-loving or exotic species. These lands include occasional buildings, structures, and unpaved roadways with pastureland,

and light to intensive agriculture. Most pastureland was developed by clearing woody riparian vegetation from the riparian area then managing it as grassland. Light agriculture includes hay fields and open land used for livestock grazing. Row crops, penned livestock, or confined animal feeding operations are in the intensive agriculture category.   These riparian and floodplain land uses vary greatly in their effect on river health. Light agriculture and pasture is generally compatible with flooding and they provide some basic floodplain functions where they have not been drained or physically cut off by berms.

Figure 3.5: Rural development covers ten percent of the mapped riparian zone.

Open space and parks

Sixty-four percent of the riparian zone remains open space (under various forms of management) and park land (Figure 3.6). These lands include properties holding remnants of preserved native habitat, or areas that were settled and altered in the past that have since been managed with the express goal of maintaining or enhancing native species and natural system function. Even with current management by open space programs, these lands continue to exhibit a wide degree of impacts remnant from previous land uses. The most disturbed open areas—such as vacant lots, abandoned roads, and naturalized roads and berms—tend to have less vegetation and are often dominated by weedy or exotic species. On the other end of the spectrum, some properties have been restored specifically to support river function by improving river-floodplain connectivity and creating the ideal physical conditions for the native flora and fauna to flourish.

These lands are also managed to provide recreation opportunities and so include infrastructure such as paved multi-use trail, bathrooms, and pavilions all of which influences natural system function. Parks dominated by turf, recreational infrastructure, parking lots and sidewalks also fall into this stressor category. Parks impair function to a much greater degree than the naturalized open spaces, because of their lack of structural diversity and contribution of nutrients and other chemicals to the river.

Figure 3.6 While open space and parks management of lands in the floodplain primarily has a positive influence of river health, infrastructure such as the bike bath in this photo is often located so close to the river that it's protection disconnects the river from a functional riparian zone .

Gravel pits and ponds

Gravel pits and ponds account for eight percent of the SOPR riparian zone land cover (Figure 3.7). Gravel mining has been a prominent industry along the Poudre floodplain corridor almost since the town was first settled. In the City of Fort Collins natural areas alone, there are more than 30 former gravel pits and ponds. Most of these are excavations filled with alluvial groundwater that are separated from the river by berms or dams. Gravel ponds represent a conversion of vegetated riparian habitat into open water, and therefore they are a direct and severe impact on riparian condition. In some cases—where they are not fully surrounded by berms and gravel pits—ponds still offer some floodplain function by providing area for overbank flows to spread, but ponds provide no floodplain roughness. Bermed gravel pits and ponds contribute to instability and poor resilience by introducing the risk of catastrophic failure and avulsion (*i.e.*, rapid abandonment of a river channel and the formation of a new one). Recovery from massive avulsions is slow and unpredictable, and it can be quite expensive if the issue must be actively addressed. The numerous examples where Front Range rivers cut new channels through gravel pits and ponds during the 2013 flood provide direct evidence of these potential risks and the consequences. Gravel pits and ponds also affect groundwater dynamics, habitat connectivity, and (potentially) water quality.

Figure 3.7: Gravel pits and ponds are a common floodplain land use in the Urban and Plains zones.

Roads and bridges

Roads and bridges affect river health in several direct and indirect ways. Highway 14 parallels the river through the Canyon zone (Figure 3.8). The valley bottom is so confined and narrow in this zone that road encroaches on the riparian zone, the floodplain, and even on the channel itself where it affects floodplain connectivity, riparian condition, river form, and resilience. Below the canyon, roads also contribute to floodplain encroachment, especially where perpendicular cross-fills consolidate flows through bridges openings. Two bridges span the Poudre in the Canyon zone, four on the Rural zone, twelve in the Urban zone, and four in the Plains zone (Figure 3.9). Bridge effects vary by design and span length, but they generally limit floodplain extent, impact riparian condition, and reduce resilience. In most cases river form and physical structure are also directly affected.

Figure 3.8: Highway 14 road fill encroachment in the riparian floodplain is common in the Canyon zone.

Figure 3.9: Twenty-two bridges span the Poudre in the study area. At left, a railroad trestle and College Avenue and at right Prospect Road.

Berms and channelization

Downstream of the Canyon Zone, a majority of the river is channelized and/or bounded by berms (Figure 3.10). These practices are important for protecting floodplain development and infrastructure, but they also have a significant impact on river ecology and health. In addition to limiting floodplain extent, which is their intended purpose, channelization and berms directly impact riparian condition and all the geomorphic indicators of river form, resilience, and physical structure. Channelized reaches have decreased sinuosity and length, limited branching or braiding, narrow and often entrenched channel dimension, increased slope, and typically homogenous bed and bank structure. Resilience is compromised by the reliance on engineered structures to maintain river form and to protect human life and property. When berms breach or when channelized reaches avulse, as they occasionally do, there is little potential for passive recovery.

Figure 3.10: Channelization and berms are common on the Poudre River as shown in the two photographs here.

Bank and channel armor

Armor—such as engineered streambanks, riprap, and concrete— is used to strengthen the riverbed and banks to maintain channel resistance and to prevent its migration or movement (Figure 3.11). These treatments work by increasing channel hardness or resistance to scour, usually with the intent of protecting development, infrastructure, and property from channel migration or erosion. Combined with channelization and berms, bank and channel armor limits the width of the channel migration zone, which is the area within which the river can safely and effectively migrate. By arresting the natural processes by which the river moves, adjusts, and maintains habitat diversity, channel and bank armor directly impacts river form, resilience and physical structure. Revetments provide resistance to these processes so that the river maintains its form despite changes that may be occurring in the channel dimension and profile upstream. The physical structure indicator is impaired by armoring since armored banks prevent the increased channel sinuosity and lateral scour that would normally maintain lateral scour pools and bank undercuts.

Figure 3.11: Bank and channel armoring is employed to increase channel resistance, protect above and below ground infrastructure or prevent river migration.

Channel structures *(such as dams, weirs)*

There are 19 dams and several other weirs and grade control structures on the Poudre in the study area. Four of the dams are in the Canyon, five in the Rural, six in the Urban, and four in the Plains zone (Figure 3.12). Dams, weirs, and grade control structures are additional channel armoring features that resist erosion and lock the channel in place. Most of the dams serve as control structures for the major water diversions, while other structures provide grade control and channel stability functions. Regardless of their intended function, most of these structures have severe local impact on river form, resilience, and physical structure. Like armoring, rigid structures prevent channel movement and adjustment, and they impose an artificial channelized dimension and planform. With heights that reach eight or more feet, diversion dams are a major impact to river profile, creating long flat slackwater sections upstream where deposition leads to homogenous plane-bed structure at the coarse scale, while at the fine scale substrate becomes embedded or armored. Most of the structures are engineered to resist scour and failure due to erosion even in extreme floods, but when they do fail there is little to no recovery potential, and expensive emergency repairs are often necessary.

Figure 3.12: There are nineteen major structures or dams on the study area. Some pose major barriers for fish (left), while others are much lower and may be passable at some times of the year (right).

Woody material recruitment and removal

Woody material was historically a very important driver of river form and function on the Poudre, but in-stream wood has become scarce in its modern-day stabilized and channelized form (Figure 3.13). Riparian development and deforestation led to a decreased supply of wood, but berms, channelization, and armoring are also important factors that limit accumulation of woody material. Unconfined rivers normally accumulate wood as they migrate through forested riparian zones, entraining trees via active bank erosion or when dead wood on the floodplain is rafted in during floods. Both of these mechanisms are now severely limited in the study area. Moreover, when large woody material does become entrained in the river, it is often physically removed as part of maintenance programs. In a natural state, large woody material and log jams in the river create overhead cover, hydraulic diversity, and structural diversity by impounding water and/or inducing localized scour that forms pools. Even today, some of the deepest pools and most complex habitat are in locations where wood has been allowed to collect and become integrated into the channel.

Figure 3.13: Large woody material in the river creates important structural complexity and habitat diversity for fish and other aquatic life (left). Beavers play an important role in the cycling of large wood in river systems (right).

Exotic vegetation

The list of exotic vegetation in the riparian corridor includes a suite of species from regulated noxious species to species that are less noxious but extremely aggressive and prolific in nature. Noxious species are not a great concern in most of the study area because there has been proactive management in City of Fort Collins Natural Areas to eradicate them over the past decade. Properties managed by other entities may have greater problems with noxious weeds, and those properties can act as a nuisance seed source to surrounding managed lands.

Non-native species impair ecosystem functions where they dominate habitat niches formerly occupied by native species. Three species that are known to heavily impact Poudre River riparian forest function are: crack willow, reed canary grass, and smooth brome. While these are non-native, none are regulated as noxious species, yet all are extremely successful at establishing and spreading, and eventually dominating habitats. As they take over, these exotic species are resistant to scour and infiltration by other species, leading to a static vegetative community that hinders the natural processes of forest renewal by decreasing the number of sunny bare sites needed for native woody species regeneration.

4 Assessment results for the indicators and metrics

4.1 Overview of river health grades

Compiled *indicator scores* produced **river health grades of B- to C- for the 18 reaches of the Poudre River** (Table 4.1). The overall grade for the Canyon zone was a B-, while the Rural, Urban, and Plains zones were all in the mid-C range. The causes of impairment to the Poudre vary by reach and zone (see Chapter 3). This chapter describes the effects of those stressors on each indicator and metric of river health.

Table 4.1: Summary of river health indicator scores and letter grades organized by zones and reaches. Numerical scores are provided to illustrate the often subtle differences in the condition of health indicators. The assessment framework for the Poudre River uses a straight academic grading scale, where 90 and greater is an A grade, 80 and greater a B grade and so on. Letter grades are indicated through color coding. A key is presented below the table.

Zone	Canyon			Rural			Urban							Plains				
Reach	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Flow Regime	77	75	75	74	74	73	73	72	72	72	69	69	69	69	69	70	77	77
Sediment Regime	91	84	84	83	82	81	83	82	81	79	79	80	79	79	79	79	79	79
Water Quality	88	77	77	77	87	87	87	87	89	89	89	89	88	88	88	86	83	83
Floodplain Connectivity	78	82	85	74	65	85	62	61	87	50	67	73	70	77	50	98	82	71
Riparian Condition	85	87	85	77	73	74	64	69	76	63	65	70	71	73	70	76	71	68
River Form	82	74	72	79	68	78	67	74	76	70	78	74	75	77	67	74	75	69
Resilience	82	79	76	79	75	76	67	77	78	69	79	77	74	75	71	76	74	68
Physical Structure	76	74	71	82	72	79	66	77	79	77	81	70	77	76	63	74	74	69
Aquatic Life	80	81	78	76	76	76	77	78	72	74	79	79	85	85	85	78	78	78
River Health	82	79	78	77	74	78	70	74	78	70	74	74	75	76	70	78	76	73
	80			76			74							75				

Grading Scale		
🟩	A	100-90
🟩	B+	89-87
🟩	B	86-83
🟩	B-	82-80
🟨	C+	79-77
🟧	C	76-73
🟧	C-	72-70
🟥	D/F	69 or low er

Before diving further into the metric level results it is helpful and important to acknowledge uncertainty and variability within this vast project. The SOPR assessment team recognizes there are various levels of uncertainty in the results across reaches because of distinctions between scientific disciplines, river reaches and local context, data sources, data years available and combinations of qualitative and quantitative assessment approaches.

4.2 River health grades by indicator

Flow regime

The flow regime indicator grades range from C to C- suggesting substantially-impaired functionality throughout the study area (Table 4.2). Impairment mainly arises from the effects of water management. Most of the fundamental physical and life-support functions are still sustained, but higher-level functioning requires active management to accommodate or mitigate the altered flow regime.

When considering the results for all three flow metrics, note that there are various degrees of uncertainty in the results across the zones corresponding to data availability or lack thereof. Most notably, the Canyon zone was evaluated using the general qualitative grading guideline descriptions and a general high level evaluation of changes to flows, in contrast to the lower three zones that were assessed quantitatively. Furthermore, the quantitative assessment for the lower three zones was conducted using gage data and grading guideline "thresholds" that originate from specific locations on the river. Therefore the further one moves from these locations, the greater the uncertainty.

Table 4.2: Summary of flow regime indicator scores and grades organized by zones and reaches.

Zone	Canyon			Rural			Urban							Plains				
Reach	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Peak Flow	81	78	78	78	78	78	78	78	78	78	72	72	72	72	72	75	88	88
Base Flow	72	72	72	68	68	65	65	62	62	62	62	62	62	62	62	58	58	58
Rate of Change	73	73	71	70	70	70	70	70	70	70	70	70	70	70	70	71	75	75
Flow Regime	77	75	75	74	74	73	73	72	72	72	69	69	69	69	69	70	77	77
	76			73			71							73				

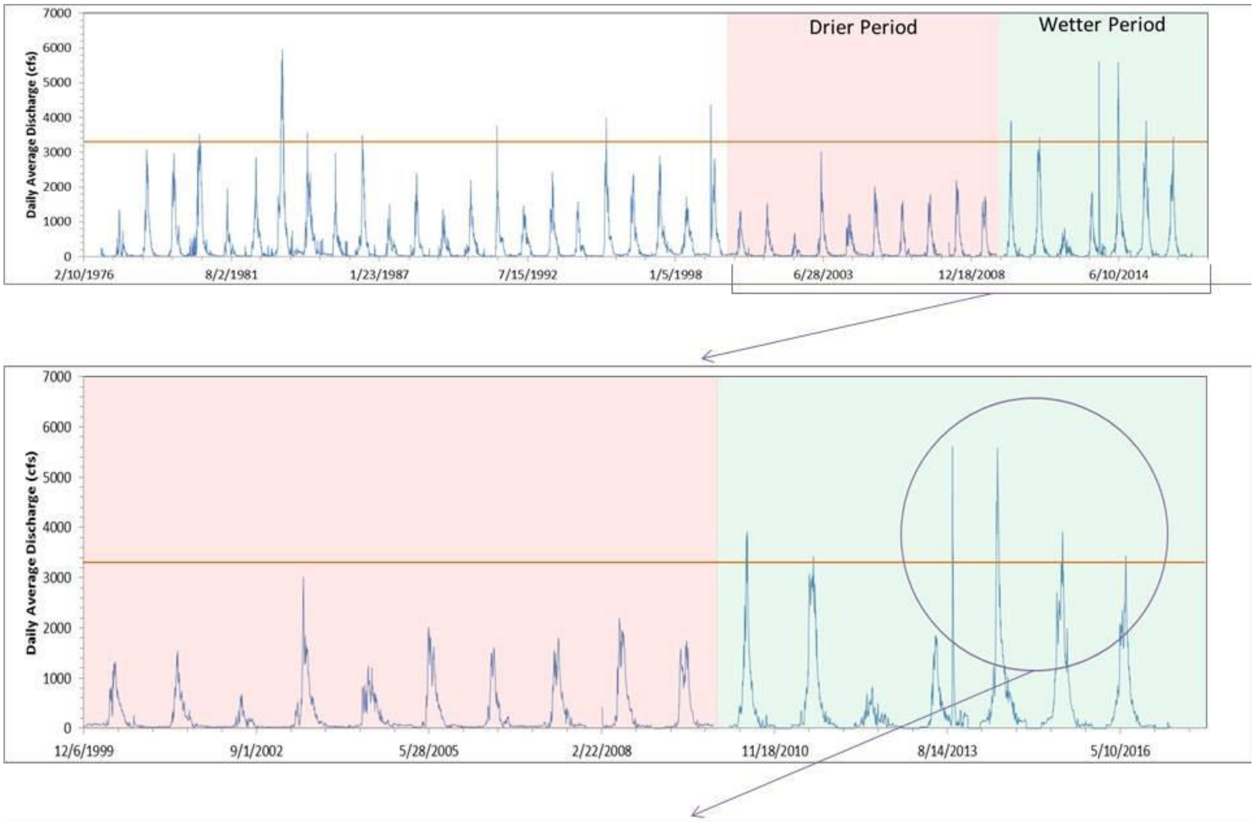
Peak flows

The reduction of peak flows results in an adverse effect on the river's ability to carry out vital functions. The C+ to C- zone level grades for this metric indicate that flows sufficient to mobilize and flush bed material do occur, but less frequently and with less certainty than needed to help support a functionally healthy and resilient river. From the upper reaches of the study area a C+ grade is reported for each reach until halfway through the Urban zone where at reach 10 the cumulative impact of multiple diversions drives the score down to a C-. In the lowest two reaches in the Plains zone, peak flow metric grades jump from C- to B+. This grade improvement represents an increased ability for the peak flows to move sediment, rather than larger or more characteristic peak flows. The improvement in functioning is due to the smaller sediment size found here, which require lower flow magnitudes to accomplish the same bed-mobilization functions. In other words the magnitude and frequency of peak flows downstream from the Boxelder gage is sufficient to support natural channel maintenance functions, such as scour and bed flushing, at a higher functioning level (B+).

The grading guidelines for the peak flows metric are based on the thresholds for river bed mobilization modeled in the ERM. Bed mobilization is critical for maintaining habitat and the life cycle needs of aquatic insects and fish that rely on clean interstitial spaces between coarse bed materials. Another important role of bed mobilization is to prevent armoring, or conversely, sedimentation. These processes can have a cascading effect on a spectrum of other important functions associated with a healthy river. The peak flow thresholds needed to perform other functions such as algae scour, channel maintenance and certain riparian processes may correlate to (but are unlikely to be the same as) the bed mobilization thresholds. But these other important functions were not explicitly analyzed for this metric.

Flows that mobilize the median-sized bed material for a given reach do not occur every year, nor must they to maintain river health. Peak flows must be analyzed over various time scales to determine whether flushing thresholds are exceeded often enough (referred to as the return interval), and for enough duration, to maintain river health. For this analysis of peak flows, the period of record from 1976-2016 for each of the three gages was analyzed for peak flow magnitude, duration, and frequency thresholds (Figure 4.1). A longer-term record is needed to compute a return interval and to characterize ecological processes and cycles that occur over long periods (decades to centuries). Looking at this 40 year period is needed to compute a return interval and is appropriate since many ecological processes and cycles occur over much longer periods (decades to centuries). However, long-term patterns do not provide information on the occurrence of recent bed mobilization in this SOPR study period (*i.e.*, 2015-2016).

A second line of evidence helps convey the current condition of the critical ecological functions driven by the peak flows. The embeddedness of riffles, as measured in the fine scale metric (page 70), provides field-based evidence indicating the degree of bed flushing that has occurred recently. Using the fine-scale structure metric alone, without analysis of the longer flow record, could be misleading, since rivers naturally experience climate driven wet-dry cycles that span years to decades. For instance, during a dry period, when flushing has not occurred for several years, the riffles may appear more embedded with fines. Therefore, the SOPR assembled multiple lines of evidence covering multiple time scales to produce a better understanding of the single most driving factor in Poudre River health.



Recent activity of flushing flows is measured in the “**fine-scale”** physical structure metric. See page 70

Figure 4.1: Daily average discharge at the canyon mouth gage (1976-2016) was analyzed for peak flow magnitude, duration, and frequency thresholds. The horizontal orange line indicates flow of 3300 cfs which was calculated in the ERM as the threshold required to mobilize the median grain size in the Rural and Urban zones. Long, medium, and short time scales are considered in the comprehensive interpretation of flushing flow functions. The fine-scale physical structure metric provides another line of evidence to determine whether flushing has occurred in the past few years.

Base flows

Base flow grades ranged from C- to F+. There is a slight downward trend in grades from the Canyon through the Plains zones due to the cumulative depletion of water during low flow periods from the 16 major diversion points located throughout the study area. Depletions during low-flow periods cause lower base flow and/or prolonged periods of low flow (Figure 4.2). Some segments of the Poudre run dry below diversions during winter. Point flow models indicate that at least three days with no flow occur per year, on average, below Greeley’s water supply diversion, and occur again at other diversion structures downstream, increasing the number to 24 days of no flow per year at the Fossil Creek Inlet Diversion (see Figure 3.1 and Tables 3.2 and 3.3).

Figure 4.2: Extremely low base flows occur regularly in reach 13.

Rate of change

Rate of change grades ranged from C to C-. Most reaches either contained at least one diversion, or have one in a proximate upstream reach. These diversions are managed such that rates at which flows rise and fall can be rapid enough to stress native plants and animals. Abrupt changes in flow that can occur when diversion gates are suddenly opened and closed can negatively impact the aquatic biota, especially during low flow periods. This metric’s scores highlight an important stress on the rivers aquatic ecosystem.

Sediment regime

Sediment regime grades ranged from A- in the Canyon to C+ in the Plains zone, indicating that the sediment regime is largely in good condition (Table 4.3). Impairment of continuity as a result from in-line reservoirs and dams was the most influential downward driver of grades.

Table 4.3: Summary of sediment regime indicator scores and grades organized by zones and reaches.

Zone	Canyon			Rural			Urban							Plains				
Reach	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Land Erosion	82	88	88	92	92	92	92	92	85	85	85	85	85	85	85	85	85	85
Channel Erosion	95	95	95	84	83	79	81	80	82	78	78	80	78	78	78	78	78	78
Continuity	95	68	68	72	72	72	75	75	75	75	75	75	75	75	75	75	75	75
Sediment Regime	91	84	84	83	82	81	83	82	81	79	79	80	79	79	79	79	79	79
	86			82			81							79				

Land erosion

Land erosion grades ranged from A- to B-. The only significant land erosion stressor in the Canyon and Rural zones is from the land cover change within the burn areas of recent wildfires. Erosion from burned areas affects the Poudre most on the reach between the Munroe Diversion and the confluence with the North Fork. Approximately 16% of the watershed area contributing to this reach is burn scar, and the reach is graded B-. The contributing watershed area more than doubles below the confluence with the North Fork, so the percent burned area in the contributing watershed drops to 7% at this point, yielding a grade of B+. The effects of the fire diminish from this point downstream.

Other stressors from land erosion such as construction disturbance, impervious surfaces, and urban stormwater runoff, become more important in the Urban and Plains zone. Some of these impacts increase sediment runoff, but most of them decrease the supply of sediment. The net effect of land erosion impacts on overall sediment regime on the Poudre is minimal, warranting a grade of B or higher through the Urban and Plains zones. Land erosion is not a critical limiting factor to the health of the Poudre River.

Channel erosion

Channel erosion grades ranged from A to C+. The Canyon zone scored the highest (A) with no significant stressors. The Poudre River is a threshold channel through the Canyon zone, where geologic controls naturally limit the amount of channel erosion. Most of the banks are also armored. Tributary watersheds in the Canyon zone are mostly undeveloped with few to no anthropogenic stressors affecting rates of channel erosion.

In the Rural, Urban, and Plains zones, the Poudre was historically an alluvial channel with river bed and banks that moved and adjusted with natural patterns of erosion and deposition. Artificial stabilization is a major human impact in these zones, where armored banks, riprap, channelization, berms, dams, weirs, and grade control structures have been employed to keep the river in place. Natural processes of erosion, deposition, and migration are severely limited by these treatments. The river through these zones behaves much more like a threshold channel in that erosion and migration occurs only during extreme events. Most of the time, there is little to no channel erosion and therefore little to no contribution of sediment from channel erosion on these reaches. While the overwhelming trend is towards a stabilized and static river channel with little erosion, there are localized segments with acute channel erosion issues. Some stabilization measures, such as the extensive use of riprap, have accelerated bank erosion in adjacent segments that are not armored, and in some cases failed stabilization efforts have exacerbated erosion.

The same impacts are present on most of the tributary streams that enter the Poudre within the lower zones. Artificially-stabilized streams usually contribute less sediment than they would in their natural state —but in some cases the opposite is true. Channel incision and accelerated bank erosion on a few tributary streams elevate sediment supply above natural levels. Some of these tributaries are streams on which stabilization measures failed. Others evolved into incised channels in response to land and water use practices and are still eroding. Retention ponds on some of these eroding tributaries capture sediment before it enters the Poudre. Overall, sediment supply from tributary reaches has probably decreased compared to natural conditions.

Continuity

In-line dams and reservoirs have the greatest impact on sediment continuity. Reservoirs trap essentially the entire sediment supply from the North Fork basin, which adds up to 54% of the Poudre's contributing watershed area when they join. Because of this impact, sediment continuity scores drop from A to D+ at the confluence, and then gradually increase moving downstream as the sediment-blocked North Fork drainage area becomes a smaller and smaller proportion of the contributing watershed. Other impediments to sediment continuity such as small in-line dams and diversion structures may be insignificant to sediment continuity because the volume of sediment trapped and stored is small compared to the annual yield and these structures are likely filled to capacity with sediment.

Water quality

When averaged across the entire study area, water quality on the Poudre River was graded B, indicating a highly functional condition, with reach scores ranging from B+ to C+ (Table 4.4). Local impairment issues are apparent, however, when the river is assessed at finer resolution. At the B grade, water quality may be impaired enough to affect the distribution and community assemblage of aquatic life, but it is still supporting essential functions well. Stressors to water quality are mostly managed or mitigated.

Table 4.4: Summary of water quality indicator scores and grades organized by zones and reaches.

Zone	Canyon			Rural			Urban							Plains				
Reach	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Temperature	86	69	69	69	86	86	86	86	90	90	90	88	88	88	88	87	85	85
Nutrients	94	92	92	92	91	91	91	91	94	94	94	88	88	88	88	86	85	85
pH	91	92	92	92	87	87	87	87	87	87	87	90	90	90	90	92	89	89
DO	89	87	87	87	89	89	89	89	89	89	89	92	92	92	92	89	84	84
Water Quality	88	77	77	77	87	87	87	87	89	89	89	89	88	88	88	86	83	83
	80			83			88							87				

Issues with temperature and dissolved oxygen concentration are the most important downward drivers on water quality and its grade. The higher water quality grades in Urban zone versus the Canyon zone may seem contrary to expectations, however, the grading criteria are set relative to water quality standards, which vary as the river changes in character. Therefore, grades relate to a correspondence with standards rather than some absolute measure of water "purity". Nutrient levels downstream of I-25 may be elevated enough to affect biological function, specifically in respect to potential changes in algal productivity and/or algal species composition in the river (a "reach 19"—downstream of the study area—was evaluated for certain water quality measures as explained below). Water treatment and ongoing active watershed management are critical to mitigate potential water quality issues and support aquatic life in these reaches below the study area.

Water temperature

Water temperature grades ranged from A- to D+. The reach upstream of the North Fork in the Canyon zone (reach 1) was graded B. Although this reach is part of the CDPHE Stream Segment 10a, which is on the state 303d list of impaired waters for temperature, an evaluation of temperature records showed that state temperature standards were not exceeded on this specific reach between 2013 and 2015. Below the North Fork confluence on reaches 2-4, however, several exceedances of the acute maximum daily temperature standard were observed over the same period, as well as exceedances of the chronic standard, maximum weekly average temperature (MWAT). These data confirm the 303d listing for this portion of Segment 10a for temperature issues, resulting in a D+ grade. Although seasonal average temperature (Apr-Oct) is within the B range, a 303d listing automatically confers a grade of D or less by RHAF grading guidelines.

The D+ grade and water quality standard exceedences for reaches 2-4 must be interpreted with broader perspective, otherwise these measures may convey an incomplete and potentially misleading picture of river health within these reaches. In general, maximum daily temperature standard exceedances occurred during two times of the year, in late March and in the summer months from June - September. Temperature standards change abruptly from cold to warm season values on April 1. It is usually during this time of year, known as the shoulder season, when warmer air temperatures begin to increase water temperatures, and exceedances may occur depending on the timing and magnitude of the spring warm-up period. Summer exceedances occur during particularly warm years, and/or when river base flows are low. Regardless of the timing of the standard exceedances, the data record indicates they are generally infrequent and of short duration. For the large majority of the time during the years 2013-2015, temperatures are well within the standards. The exceedances, do however, highlight the importance of continued temperature monitoring for both aquatic life and water quality perspectives, as increases in the frequency and magnitude of exceedances may signal the presence of anthropogenic stressors, or climatic trends toward hotter and drier summers and earlier spring snowmelt, both of which could have considerable impact on overall river health and function.

The exact causes of the observed standards exceedances in reaches 2-4 are currently unknown, although a variety of factors may act together to result in relatively warmer water temperature in the river including the proportion of North Fork and Mainstem Poudre flows, overall river flow volume, diversions and inflows, in-channel reservoirs and weather. Figure 4.3 further illustrates the higher temperatures in reaches 2-4, as compared to upstream and immediate downstream reaches.

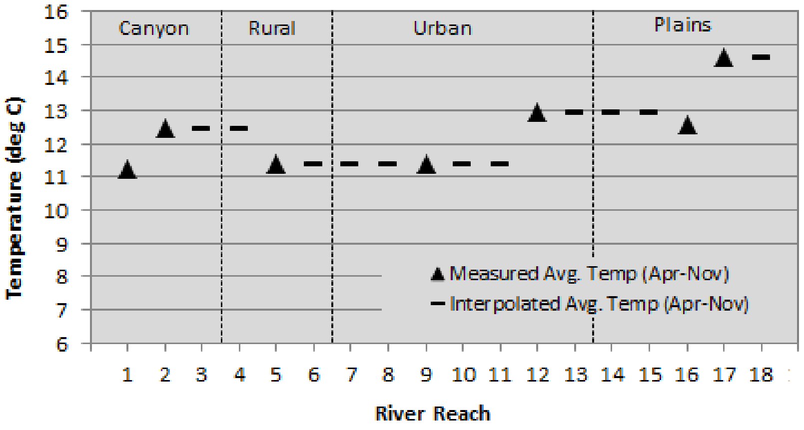


Figure 4.3: Reaches 2, 3 and 4 of the Poudre showed warmer temperatures than upstream and immediate downstream reaches, as shown in this graph of 2015 average temperatures by reach for the months of April – November, 2015.

Water temperature grades improve to B in reach 5 of the Rural zone, just downstream of the 303d-listed segment. This segment receives cold-water discharge from Horsetooth Reservoir via the Hansen Supply Canal which may mitigate some of the higher temperatures that drive exceedances in the river upstream. According to CDPHE Regulation #38, the river transitions from a cold-water to a warm-water designation at Shields Street, between reaches 8 and 9. Since water temperature standards are based on excessive heat, the warm-water designation at this point means that standards below Shields Street are warmer. While water temperature continues to increase through the Urban zone, the improved grades (A-) on reaches from Shields to Mulberry are more a reflection of the change in designation from cold-water to warm-water and the less-stringent standards that go with it.

Both cold and warm season average water temperatures increase gradually downstream through the Urban and Plains zones, and this trend is reflected by a corresponding decrease in grades from A- to B for reaches from Mulberry to I-25. Increasing temperature may be attributed to the cumulative effects of decreased streamflow due to diversions, as well as inputs of treated wastewater effluent and urban stormwater runoff, which are usually warmer than river water. Temperature monitoring east of I-25 indicates that the warming trend continues downstream below the study area.

Nutrients

Nitrogen and phosphorus monitoring reveals little to no nutrient impairment anywhere in the study area. Grades for the nutrient metric (average of nitrogen and phosphorus grades) are in the A to B range, indicating reference standard to highly functional condition throughout— though there is a slight downward trend through the Urban and Plains zones. The slight increase in nutrient enrichment on the lower reaches is likely due to return flows from irrigated and fertilized areas within the urban and residential developments, agricultural runoff, and treated wastewater effluent.

Consistent with other indicators and methods employed in this SOPR assessment, water quality conditions are evaluated and reported for the 18 reaches of the study area, which ends where the Poudre River crosses I-25. However, it is recognized that the influence of the City on water quality is not fully represented by this geographical scope. It was, therefore, determined that water quality would be evaluated further east of I-25, below the point where discharge from Fossil Creek Reservoir enters the Poudre, as this location includes the return of local communities' reclaimed wastewater to the River. Although presentation and discussion of results throughout this report include only the common 18 reaches, where notable, water quality results for the additional site, termed reach 19, are included.

Within reach 19, measured nitrogen concentration was in the C range, and measured phosphorus was in the F range, resulting in a combined nutrient metric grade of a D for this reach. Given the drastic increase in nutrients at this station, and the lack of any other apparent stressors, Fossil Creek Reservoir discharge is the most probable cause of nutrient loading. The water quality in Fossil Creek Reservoir reflects the combined influences of Poudre river water, reclaimed municipal wastewater, local stormwater runoff, and seasonal reservoir dynamics. Total phosphorus concentration at this site exceeded CDPHE's proposed warm-water standards of 170 µg/L (based on Colorado's Water Quality Control Commission Regulation #31—The Basic Standards and Methodologies for Surface Water) more than once over the last five years. If CDPHE formally adopts the 170 µg/L phosphorus standard, this section of the Poudre will be considered impaired due to nutrient loading.

pH

Measured pH values were within normal ranges (6.5 - 9.0) at all stations during the monitoring period, indicating no functional impairment on any of the study reaches. Grades ranged from A- to B+, owing to slight variations and occasional readings at the margin of the A-grade range. The grade decreased slightly to B downstream of Fossil Creek Reservoir outlet in reach 19, reflecting the influence of wastewater effluent and/or discharge from Fossil Creek Reservoir on river water quality.

Dissolved oxygen

Grades for dissolved oxygen were A- to B, and all sites met the water quality standard for spawning fish. Most sites throughout the study area scored a B+, but the lowest two reaches in the Plains zone (17 and 18) scored a B. These reaches on the river have the lowest seasonal flow conditions and receive warmer, nutrient-rich water from two upstream wastewater reclamation facilities. These inputs can reduce dissolved oxygen concentrations in the river water when biological oxygen consumption from metabolism and aerobic decomposition outpaces oxygen production from photosynthesizing aquatic plants and algae. Other stressors that may decrease dissolved oxygen concentrations include a lack of turbulence or physical mixing, stagnant water, elevated temperatures, and the accumulation of fine sediment that further increases oxygen demand. Dissolved oxygen concentrations drop further into the B- range in reach 19, below the confluence of Fossil Creek.

Floodplain connectivity

Overall, the floodplain connectivity indicator received a C grade (Table 4.5). Only one metric (floodplain extent) influenced this grade, as discussed below.

Table 4.5: Summary of floodplain connectivity indicator scores and grades organized by zones and reaches.

Zone	Canyon			Rural			Urban							Plains				
Reach	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Floodplain Extent	78	82	85	74	65	85	62	61	87	50	67	73	70	77	50	98	82	71
Floodplain Connectivity	78	82	85	74	65	85	62	61	87	50	67	73	70	77	50	98	82	71
	81			75			68							79				

Floodplain extent

The floodplain extent metric considers the physical (topographical) connection between the river channel and its floodplain and the frequency at which flows inundate the floodplain. Conditions vary considerably through the study area, resulting in a wide range of scores. In the confined Canyon zone, there is limited natural floodplain, and connectivity depends almost entirely on the degree to which road fill for Highway 14 encroaches on it. Diversion dams and bridges are additional physical factors affecting floodplain connectivity where they consolidate flows between wing walls and over spillways. The river in the Rural, Urban, and Plains zones is not geologically confined and, historically, the natural floodplain area was up to two miles wide in places. Over time, however, that width has been deliberately decreased—through berms and channelization—to make use of the floodplain for a variety of purposes.

Floodplain connectivity is a keystone indicator because it is a fundamental requirement for a functional and resilient riparian habitat (Figures 4.4). An undeveloped floodplain that is well-connected to the river is critical for maintaining riparian habitats and dissipating potentially damaging flood energy. A healthy and resilient river needs an effective channel migration zone within which the river can move and adjust to disturbance. The C and C+ grades for floodplain connectivity on the Rural and Plains zones indicate a an impaired, but still modestly-functional floodplain. The D+ grade for the Urban zone highlights the legacy of land uses in the floodplain, many of which are difficult (or slow and costly) at best to rectify. The reach-scale grades vary considerably with most reaches scoring from B+ to D. Two reaches scored F, indicating a profoundly impaired and non-functional condition. Reaches with low grades for floodplain connectivity also tend to have poorly functioning riparian areas and low capacity for resilience (Figure 4.5).

Figure 4.4a: The five-year water surface extent between College Ave. and Lincoln St. (reach 10) shows an entrenched channel with limited floodplain connectivity due to natural bedrock and constructed berms.

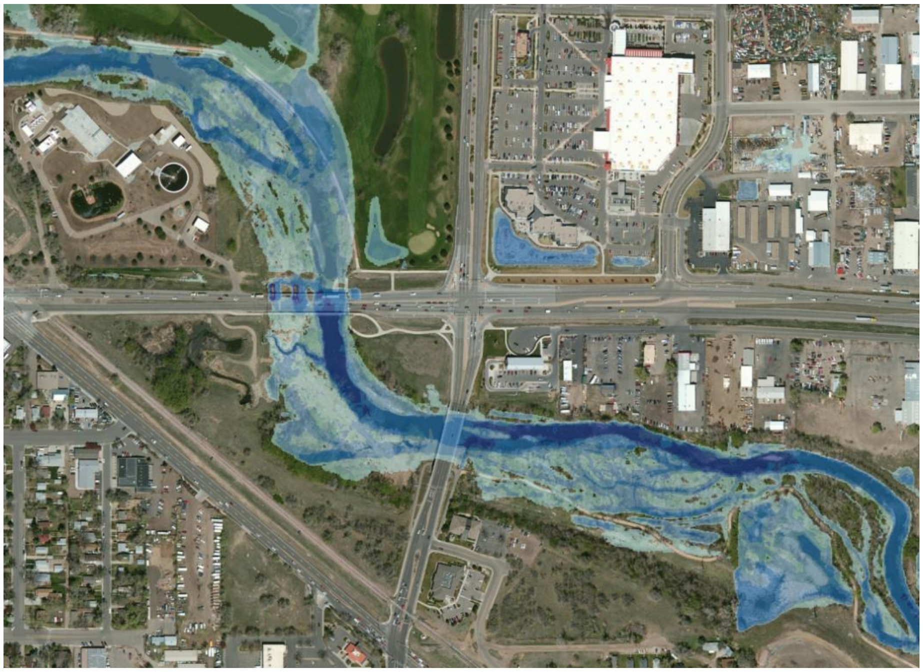


Figure 4.4b: The five-year water surface extent from the Woodward campus to upstream of the Timnath Canal Diversion (lower end of reach 11 and upper half of reach 12) shows a less entrenched channel with a better-connected floodplain.

Figure 4.5: Floodplain connectivity is critical for river health, and it also reduces risk to infrastructure. During extreme high flow events, where floodplain-river connectivity is poor and development in the riparian zone is extensive, there is greater risk of flood damage to infrastructure. The photograph at left shows a connected floodplain at a former golf course (currently the Woodward site and Homestead Natural Area). Near the bottom left of the photograph, however, the intersection of Lemay Avenue and Mulberry Street limits floodplain connectivity and floodwaters threatened to over top Lemay Avenue. In contrast (right), at the ELC, the riparian zone is managed for natural habitats and the topography allows for the river to be connected to the immediate zone next to the river, resulting in a resilient situation

Riparian condition

Vegetation structure is the primary metric informing the riparian condition score, with the other two metrics of habitat connectivity and contributing area exerting a relatively smaller influence. The riparian condition indicator scores varied from B to D indicating that all reaches still maintain at least a rudimentary riparian zone (defined as the corridor extending 100m from each bank) (Table 4.6).

Table 4.6: Summary of riparian condition indicator scores and grades organized by zones and reaches.

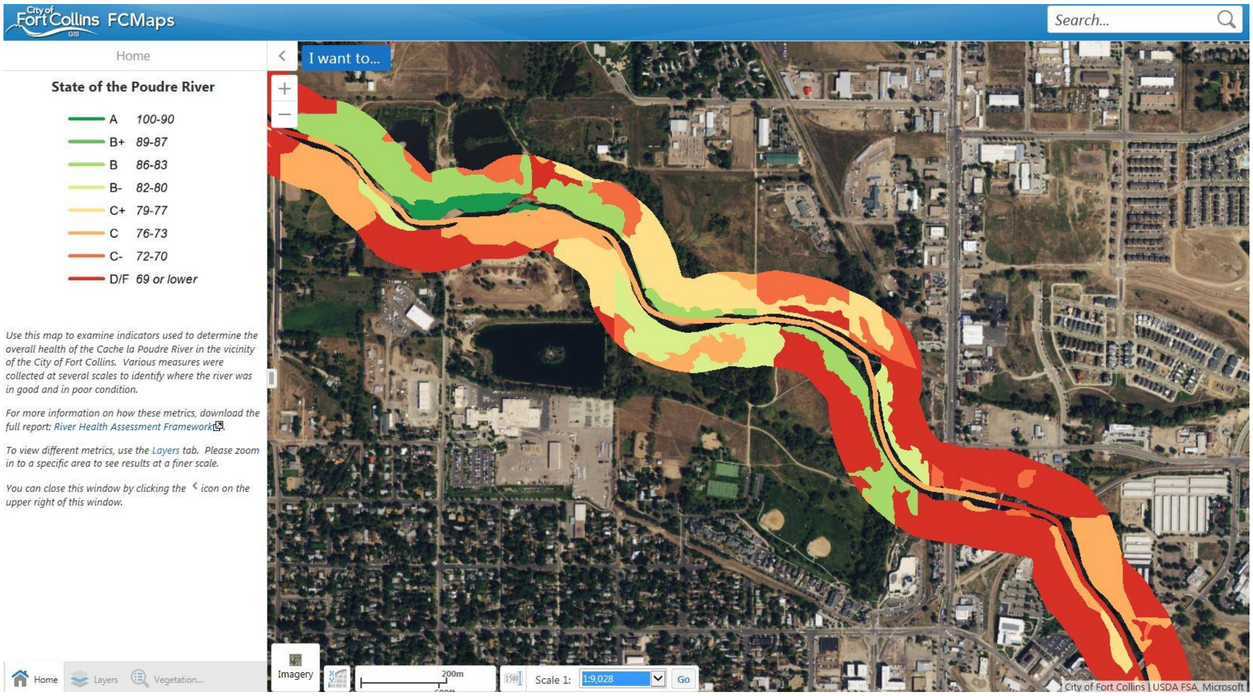
Zone	**Canyon** (100 ac.)			**Rural** (449 ac.)			**Urban** (571 ac.)							**Plains** (427 ac.)				
Reach	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
Riparian Acreage	*16*	*59*	*25*	*178*	*95*	*176*	*149*	*77*	*105*	*46*	*72*	*57*	*65*	*75*	*53*	*161*	*63*	*75*
Vegetation Structure	83	86	83	75	70	72	64	68	74	64	65	70	70	71	68	74	69	66
Habitat Connectivity	92	92	92	88	81	84	63	72	88	60	68	75	78	82	78	92	79	79
Contributing Area	92	92	92	80	88	81	68	70	76	62	60	62	67	78	78	80	74	76
Riparian Condition	85	87	85	77	73	74	64	69	76	63	65	70	71	73	70	76	71	68
	86			75			68							73				

Vegetation structure

The vegetation structure assessment considered various factors needed for sustainability and resilience of riparian habitat such as land use and cover type, habitat patchiness and interspersion, diversity in height structure, presence of problematic non-native species, and regeneration of native tree species. The reach scores are informed by the composite scores of individually-mapped patches or "polygons." The assessment was conducted at the patch level and averaged across each reach. There was often diversity in scores across the patches within a reach, with forested patches tending to have higher scores than non-forested ones.

Vegetation structure grades range from B to D with a strong demarcation of scores between reaches secondary to changes in land use and land cover and degree of connection with the river. Vegetation is absent or greatly altered in large portions of the historical riparian zone. In cases where no appreciable vegetation was present, the assigned grade was an F. Patches with vegetation structure more closely resembling natural conditions scored higher. Land cover determines the potential to support healthy riparian habitats. For the analysis, land use and land cover were the first filters to determine grading and also to identify candidate patches for field assessment. Appendix D provides the results corresponding to these classes, along with a basic description, a summary of grades, and the relative cover of each class.

Patches of quality riparian habitat may be present even on reaches with low vegetation structure scores (Figure 4.6a and b). Remnant patches of forest, scrub-shrub, and wetland are commonly embedded in more developed landscapes, especially on City of Fort Collins Natural Areas parcels. Remnant patches of high-quality riparian vegetation may have positive habitat benefits that exceed their contribution to overall reach scores since they provide urban habitat oases and refugia (Figure 4.6a and b).



Use this map to examine indicators used to determine the overall health of the Cache la Poudre River in the vicinity of the City of Fort Collins. Various measures were collected at several scales to identify where the river was in good and in poor condition.

For more information on how these metrics, download the full report: River Health Assessment Framework.

To view different metrics, use the Layers tab. Please zoom in to a specific area to see results at a finer scale.

You can close this window by clicking the ‹ icon on the upper right of this window.

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Figure 4.6a and b: Images from the SOPR online mapping tool illustrate how patches of naturalistic riparian vegetation provide high quality habitat amidst otherwise developed areas. The top image shows Shields Avenue to Linden Street in downtown Fort Collins (reaches 9, 10, and 11). The bottom image shows the river above and below Timberline road (reaches 12, 13, and 14). The primary driver of vegetation structure is connectivity with river flows which is particularly poor in the areas from College Avenue to Linden Street (bottom right Figure 4.6a). The yellow circle on Figure 4.6b shows the location of the photograph shown in Figure 4.7

Figure 4.7: A highly functional riparian forest can be adjacent to very poor-scoring riparian zone. This location of this photograph is provided in Figure 4.6b.

Eight sub-metrics were used to grade vegetation structure of patches with natural cover types such as forests. A majority of the field-graded habitat patches (especially within the Urban and Plains zones) are located on public lands managed by the City of Fort Collins (Natural Areas or Parks Departments) or CSU.

Comprehensive results for all polygons for all submetrics are also presented in Appendix D. As well, comprehensive results are presented for public lands only that are owned and managed primarily for conservation of natural habitats (like the City of Fort Collins Natural Areas.)

Vertical Complexity

Vertical complexity of wooded patches was graded B, on average, indicating highly functional condition with minor impairment. Wooded habitat typically has three layers of vegetation: herbaceous, shrub, and tree and all of the patches evaluated had at least two vegetation layers. When a stratum is missing, it is usually the shrub layer. There are several reasons for the loss of shrubs in forests. Primary causes are agriculture or landscaping, hydrologic alteration, overgrowth of crack willow that results in large patches of shaded areas for long periods of time, and lack of natural physical disturbance that maintains and renews shrub populations.

Canopy species

Native cottonwoods are most commonly the dominant canopy species, although crack willow sometimes dominates and is often the second most -common species. The average score for canopy species submetric in canopy forest patches is B.

Sub-canopy species

Sub-canopy composition also generally leans toward a native-dominated composition, with exotics such as Chinese elm and crack willow commonly next in frequency. An increasing presence of green ash is observed in the Urban and Plains zone. While this species is considered native, it is likely to alter the trajectory of these forests and their future composition, but exactly how is not well understood yet. Grades for the sub-metric are B, on average, in the Canopy and Sub-canopy Forest patches, while scrub-shrub sub-canopies grades average C+.

Figure 4.8: Canopy and subcanopy dominated by native cottonwoods and associated desirable "vertical complexity" are observed adjacent to the multi-use Poudre Trail at Lions Park in the Rural zone.

Shrub layer

The shrub layer is significantly diminished in riparian forest habitats along the Poudre (as explained above), but where it exists it is still usually a functional stratum with grades of C to C+. In scrub-shrub cover class the stratum tends to be in outstanding condition (A) — being dominated by a dense coverage of native sandbar (aka, coyote) willow. Scrub-shrub habitat has become limited in distribution, however. Almost all of the scrub-shrub habitat patches are immediately adjacent to the river where a narrow band of fluvial disturbance along the channel still supports willows and other shrubs that require the bare ground and wet conditions to reproduce and establish. Areas farther away from the stabilized river channel are only exposed to fluvial disturbance during extreme flood and they tend to be dry, and are therefore not conducive to shrub establishment.

Problem herbaceous species

Problem herbaceous species are a significant cause of impaired function on some riparian habitat types. Canopy forest, sub-canopy forest, and scrub-shrub patches scored in the B to C+ range, while emergent wetlands averaged C-. In wooded habitat, reed canary grass, Canada thistle, and leafy spurge are the common problem herbaceous species, but infestations are rarely extensive. Broad-leaved cattail, a common problem species, dominates most of the emergent wetland adjacent to the Poudre, often to the near exclusion of other herbaceous species.

Problem woody species

Problem woody species are not a major issue on most wooded riparian habitat along the Poudre, and scores for this sub-metric averaged A- to B. Crack willow is not considered a significant problem where it is only present occasionally, but it is a problem where it forms homogenous thickets or dense, impenetrable forest canopy. It is by far the most common problematic woody species yet its impact on function can be both positive - for instance as it provides bank stabilization- and negative when it significantly limits resources available for native species. Tamarisk—an invasive species that is common in neighboring watersheds— was only observed in one small stand of a few individuals at the ELC. Russian olive, an invasive tree species, occurs throughout the Rural, Urban, and Plains riparian zones, but extensive eradication efforts over the past decade by the City of Fort Collins has been effective such that very infrequently is it dominates the forest sub-canopy.

Patchiness and interspersion

Results for patchiness and interspersion follow a similar pattern to those for vertical complexity. In wooded habitats the average grade is B-. Decreased patchiness is often the result of direct impacts such as tree and shrub removal, land clearing, or development. Riparian vegetation structure has also become homogenized due to an altered disturbance regime and a reduction in system dynamism. Much of the river is artificially stabilized so that the natural meandering, avulsion, and deposition processes that would normally drive plant succession, diversity, and forest regeneration have been lost. Wetland emergent habitats usually have poor patchiness and interspersion because most of them have become overgrown by cattails.

Native tree species regeneration

Regeneration of native tree species—particularly cottonwoods— has been substantially curtailed by effects of water management and disconnection of the river from its floodplain. Owing to various floodplain alterations, such as channelization and berms, the opportunity for establishment of native trees has been limited, but it does still occur and it was common in forested and subcanopy patches (Figure 4.9). In cover types where native tree species regeneration would be expected—including canopy and sub-canopy forest, scrub-shrub and emergent wetland—this metric averaged a C, ranging from D+ in wetlands to B- in scrub-shrub patches. Regeneration was good in scrub-shrub patches because they tend to be near the channel and exposed to overbank flows. [Note that the lack of tiny seedlings or very young saplings was not taken to indicate a lack of regeneration, because regenerative floods are relatively uncommon events. Therefore, the main criterion for judging regeneration was the presence or extent of a multi-generational age structure.

Figure 4.9: Germinating cottonwood seedlings established readily at McMurry Natural Area when physical connectivity was restored such that annual spring flows provided basic habitat conditions.

Floodplain position

This sub-metric uses the floodplain position patch classification, which includes three categories: riverine, depressional, and terrestrial. Sixty-two percent of the riparian zone is riverine, meaning that is still effectively connected to the river. Eleven percent of the floodplain is now depressional (*i.e.,* mostly gravel ponds) and disconnected from the river by berms. The remaining 27 percent of the riparian zone has been terrestrialized and isolated from the river, except perhaps during the largest flood events.

Habitat connectivity

The habitat connectivity metric is a measure of the degree to which riparian habitat is biologically connected with surrounding riparian habitat, or conversely, the degree to which habitat has become fragmented or isolated. Habitat connectivity ranged from an A- in the Canyon zone and ELC to a D- in the heart of the Urban zone. While D- indicates very poor connectivity, it also signals that connectivity has not been totally eliminated. Organisms can still move throughout the entire study area, even if rates of movement may be greatly reduced through the urban bottleneck). Connectivity has been fairly well preserved upstream and downstream of the developed urban areas, and even in the Urban zone there are islands of good-quality riparian habitat that provide refuge to the animals that do make it through dangerous and stressful areas (Figure 4.10).

Contributing area

This metric reflects the level and type of land-use change that has occurred in the area surrounding the riparian corridor. Certain land uses, such as parks, still have some positive benefit as buffers between riparian habitat and developed areas. Riparian areas directly in contact with more intensive land uses such as urban development, on the other hand, are adversely affected. Reach-scale contributing area metric grades from A- to D- roughly parallel scores for habitat connectivity since contributing area is affected by the same types of land-use stressors. Generally speaking, the contributing area is in fairly good condition, reflecting the rural uses surrounding most of the riparian zone. The obvious exception to this is in the Urban zone, where the contributing area has a generally negative effect on river health.

Figure 4.10: The presence of mink along the Poudre near is an indication that the food webs they rely on as predators (and associated habitats of their prey) is fairly intact.

River form

On the reach scale, river form grades ranged from a D to a B-, averaging a C for each zone (Table 4.7). Planform shape of the river was the most impaired of the three metrics, while cross-sectional profile was the least. The planform shape of the river has generally been straightened and simplified through channelization and armoring. The other two metrics of river form have often been able to adjust, at least in part, to the newly derived planform shape.

Table 4.7 Summary of river form indicator scores and grades organized by zones and reaches.

Zone	Canyon			Rural			Urban							Plains				
Reach	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Planform	78	74	73	77	66	72	68	71	73	62	75	77	70	67	64	71	72	65
Dimension	84	74	71	78	70	78	66	75	77	69	77	71	76	79	69	76	75	69
Profile	85	73	72	81	68	85	66	77	79	80	83	76	80	85	68	75	77	72
River Form	82	74	72	79	68	78	67	74	76	70	78	74	75	77	67	74	75	69
	76			76			73							73				

Planform

Planform describes the river's form in terms of length, sinuosity, meander patterns, and branching. Reach-scale planform grades range from C+ to D- with the lowest score occurring in the channelized, heavily riprapped, and bermed reach between College Avenue and Lincoln Street. At the sub-reach scale, scores range from A- to F (Tables 4.8a and b). The highest scores are on reaches that are not channelized or stabilized by armored banks, grade control, or bridge crossings. On these reaches, the river is able to meander naturally and adjust its planform in response to changing boundary conditions. The lowest scores occurred on channelized reaches with diversion structures, bridges, and heavily armored banks.

The Poudre River is channelized through most of the Rural, Urban, and Plains zones. The naturally complex, meandering, braided, and branched channel form has been simplified to a much straighter and single-threaded channel form which is maintained with berms, riprap, and grade control structures. It has essentially been converted from a dynamic "alluvial" river system—one that would naturally move and adjust in a gradual fashion—to a "threshold" system that is artificially locked into place and can only move or adjust catastrophically when stabilization measures are overwhelmed during extreme events.

When the river does overcome stabilization measures, and it begins to meander or form branch channels, it is usually reconstructed into its artificial, single-channel form. Lyons Park is a prime example of this back-and-forth pattern. During the 2013, flood this section of channelized river eroded through its armored bank and migrated 50 feet laterally to increase sinuosity and decrease slope. Within two years the river channel was returned to its pre-flood position, and the bank was backfilled and re-armored. In most cases, maintaining the present channelized and relatively straight single channel river planform is necessary to protect infrastructure and development, but this generally has negative impacts on river form, function, and resilience.

In some cases the channelized and straightened river form may have arisen due to a combination of natural and anthropogenic reasons. On the ELC in the Plains zone, approximately 3100 feet of the river became straightened when it avulsed into a large ditch on the floodplain in the 1990s (Figure 4.11).

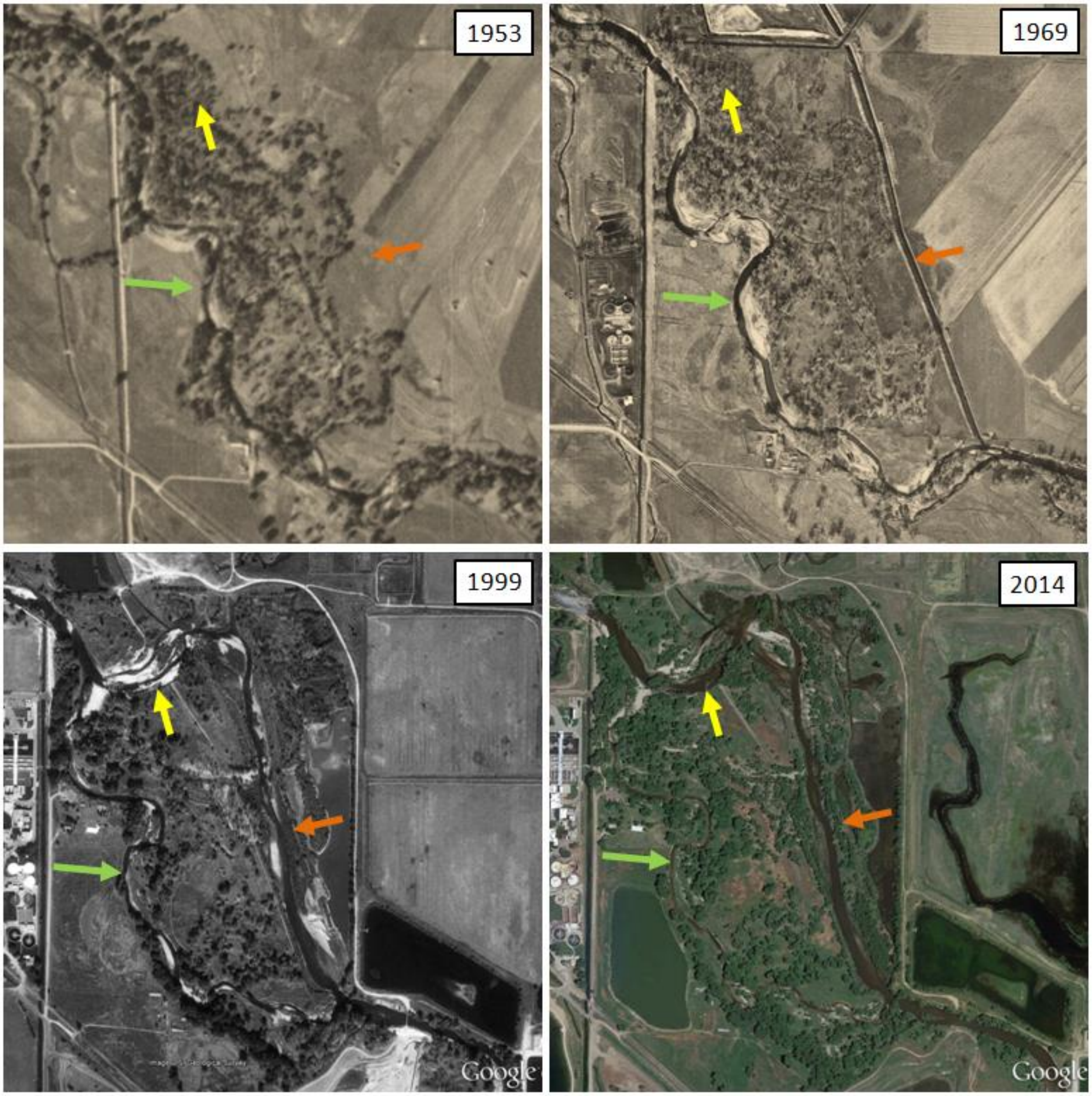


Figure 4.11: The straight single-channel planform of 3100 feet of the Poudre River on the Environmental Learning Center was formed in the 1990s when the river cut into and started flowing through a large floodplain ditch, abandoning its historic sinuous alignment. The time sequence of aerial photos shows the historic channel alignment (green arrow), avulsion point (yellow area), and current alignment through the ditch (orange arrow).

Table 4.8a: Chart showing grades of the geomorphic metrics and indicators in the two upper study zones. Colors corresponding to metric grades are shown for each of the 99 sub-reaches. Colors corresponding to indicator grades are shown for the 18 reaches. Bar lengths are scaled to the actual length of reaches and sub-reaches. Segments affected by floodplain encroachment, bank/channel armor, and bridge or dam structures are also shown.

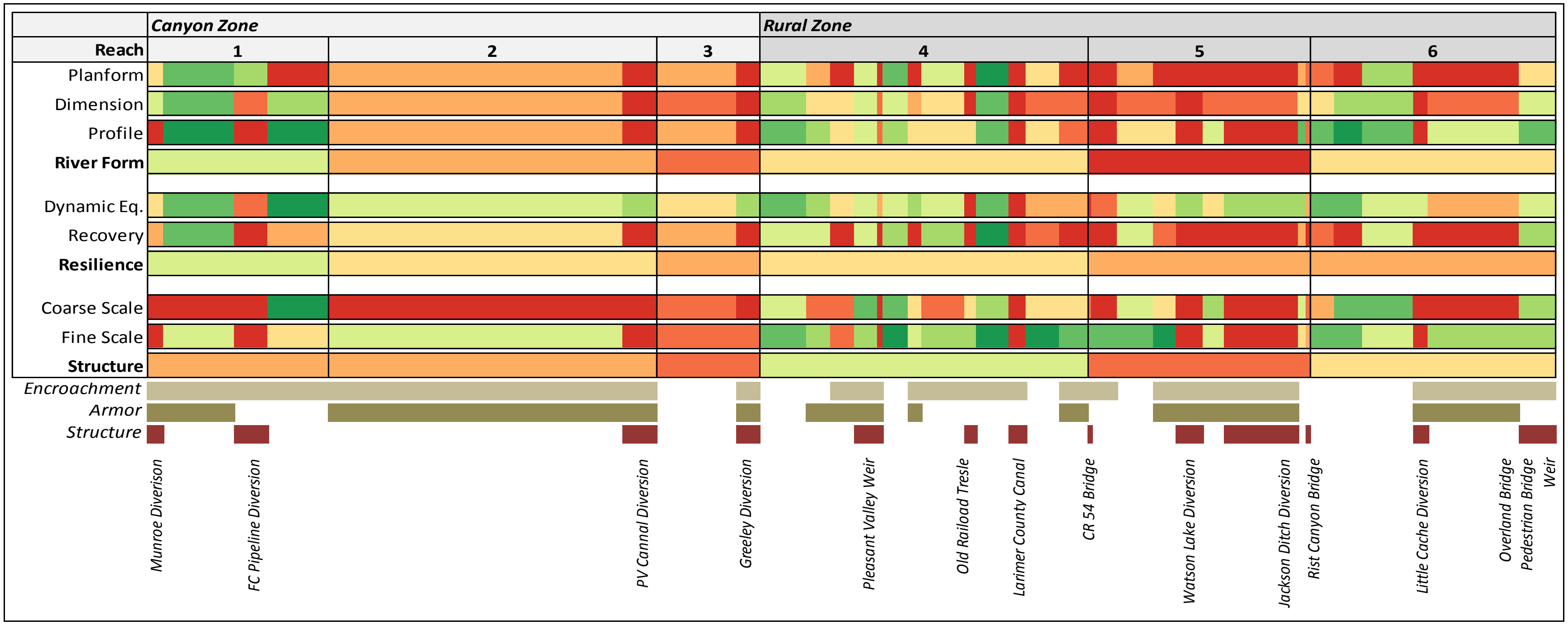
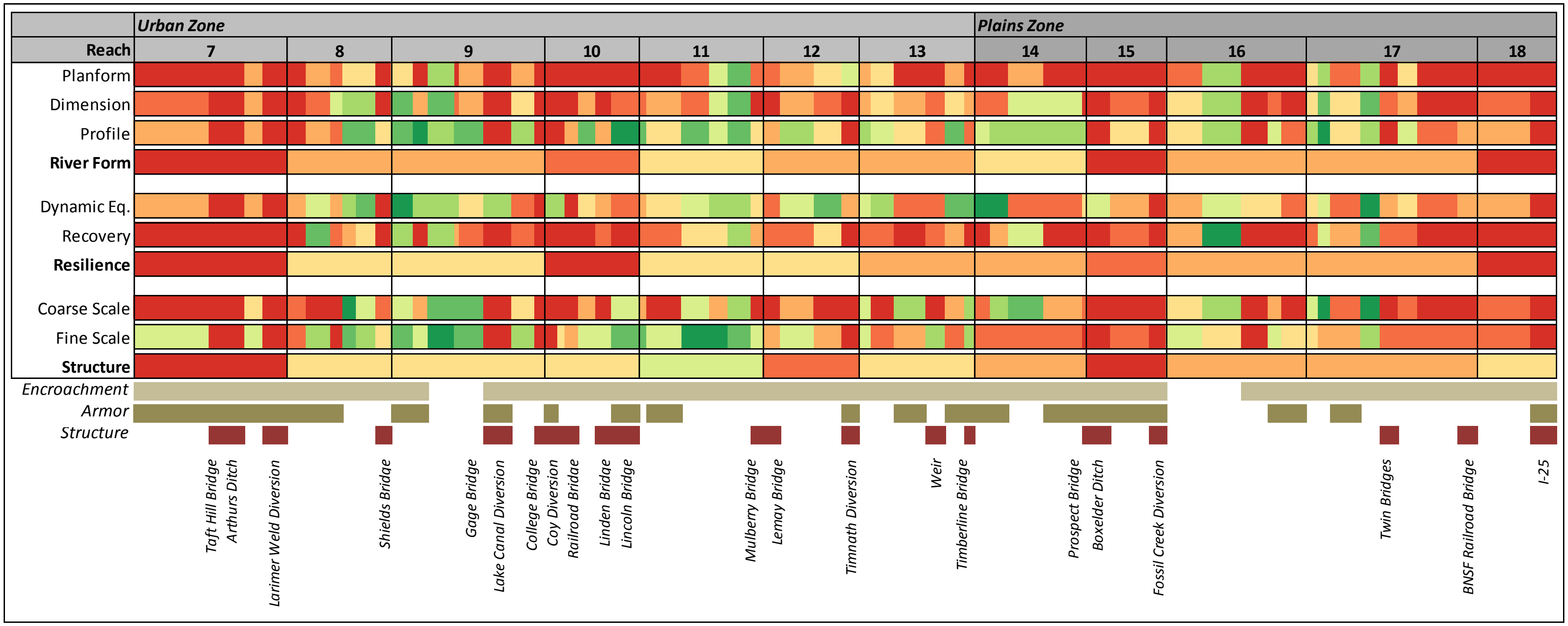


Table 4.8b: Chart showing grades of the geomorphic metrics and indicators in the two lower study zones. Colors corresponding to metric grades are shown for each of the 99 sub-reaches. Colors corresponding to indicator grades are shown for the 18 reaches. Bar lengths are scaled to the actual length of reaches and sub-reaches. Segments affected by floodplain encroachment, bank/channel armor, and bridge or dam structures are also shown.



Dimension

Dimension defines the cross-sectional size and shape of the river channels and floodplain. Dimension grades range from B to D over the 18 reaches, and sub-reach grades range from B+ to F (Tables 4.8a and b). The farthest upstream reach, from Munroe Diversion to the North Fork, scored highest, as there are few stressors directly affecting channel dimension in the geologically-confined canyon setting. Downstream of the canyon, increasing channel modification and direct impacts increase entrenchment, channel volume, and width-depth ratio to varying degrees. The lowest grades occur at channel structures such as diversion weirs, dams, and bridges where the channel is often moderately entrenched, enlarged, and either over-wide or over-deep. Berms, and elevated road grades and pedestrian trails along the river disconnect it from its floodplain, creating moderately to severely entrenched channel conditions. In most of the channelized reaches, the active channel dimension has been greatly enlarged to accommodate peak flows and floods. This means that during most of the season, low flows are spread thinly and discontinuously over wide channel bottoms.

Profile

Profile describes the longitudinal slope of the river bed. At the reach scale, grades for profile range from B to D, and sub-reach grades range from A to F- (Tables 4.8a and b). Channel profile is altered by changes to planform shape and in-channel structures. On the reaches in the Canyon zone, river sinuosity is unchanged, but many of the Rural, Urban, and Plains zone reaches have been channelized and straightened. Decreased branching and sinuosity leads to an overall increase in slope over the length of the river. Therefore, the river is steeper than it was naturally, but most of the increased gradient occurs over very short segments at the drops below diversions dams and grade control. Every diversion weir and dam acts as a grade control structure that creates a flattened bed slope upstream and a sudden steep drop below.

The lowest grades for the sub-reaches are often just above diversions. Sub-reaches with the large diversion dam structures such as the Larimer-Weld Diversion and Cache la Poudre Reservoir Inlet Canal score in the F range, indicating severe changes to profile represented by long segments of very low gradient bed slope upstream and steep drop of four to eight feet or more on the downstream side of the structure. Grade control at most of the major bridges has a similar—though less extreme—effect. The lowest-scoring reaches are reach 5 from County Road 54 to Rist Canyon Road in the Rural zone, and reach 15 from Prospect Road to Fossil Creek Reservoir Inlet Ditch on the Plains zone. Both of these reaches have multiple large diversion dams and bridges that create an artificial stepped-slope river profile.

Resilience

In the four zones resilience indicator zone grades ranged from B- to C and for the 18 reaches the grades ranged from B- to D (Table 4.9). Dynamic equilibrium is at least functional along the entire SOPR study area and half of the reaches fall in the highly functional B range. Score for the recovery metric, on the other hand, ranged from C+ to D-, and this metric drove down the overall resilience indicator score. Recovery potential was low mainly because of the reliance on artificial channel stabilization. When artificial stabilization measures do ultimately fail, it leaves the system in such a state that it has little chance of recovering to a healthy and stable state on its own.

Table 4.9: Summary of resilience indicator scores and grades organized by zones and reaches .

Zone	Canyon			Rural			Urban							Plains				
Reach	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Dynamic Equilibrium	86	82	79	81	81	80	71	79	82	75	81	81	79	77	75	77	76	72
Recovery	79	77	73	76	68	72	63	75	73	62	77	73	69	72	67	74	72	64
Resilience	82	79	76	79	75	76	67	77	78	69	79	77	74	75	71	76	74	68
	80			77			74							73				

Dynamic equilibrium

Dynamic equilibrium is a component of stability that depends on the balance of sediment supply and river energy. Excess sediment supply or decreased energy leads to accumulation of material—a process known as aggradation. Decreased sediment supply or increased energy leads to excess scour and erosion that can cause channel incision and/or widening. In the Canyon zone, the Poudre is a threshold river which means that sediment transport capacity, a function of energy, is much greater than sediment supply. Dynamic equilibrium is not normally important for maintaining stability on these types of reaches since it is maintained by a resistant bed and banks of bedrock and boulders. Decreased grades for dynamic equilibrium on the Canyon zone reaches, therefore, reflect acute impacts to sediment transport capacity from in-line dams that cause sediment to aggrade upstream.

Downstream of the Canyon, in the Rural, Urban, and Plains zones, the Poudre was historically an alluvial river. Alluvial river channels are not held in place by naturally-resistant bed and banks—rather, the bed and banks consist of material that can be moved by the river. They naturally move and change shape due to scour and deposition processes. Dynamic equilibrium is normally very important for maintaining stability on alluvial rivers, as the balance between sediment supply and river energy is what maintains proper size and shape. Although the river was historically an alluvial channel in these zones, it is now mostly functioning as a threshold channel due to artificial channelization and stabilization. Grade control structures and bank armor are the resistant features that hold the river in place on many reaches, rather than natural geological features or dynamic equilibrium.

Grades for dynamic equilibrium on the Rural, Urban, and Plains zones generally reflect the degree to which the reach depends on artificial structure to maintain stable form. Reach grades are B- to C- and sub-reach grades range from A- to F+ (Tables 4.8a and b), reflecting the degree to which existing channel configuration maintains sediment transport in the existing flow and sediment regime without either aggrading or degrading. Grades in the A-B range indicate reaches where the alluvial dynamic equilibrium processes are still functioning. Most reaches are in the C range, indicating the presence of moderate to severe stressors such as channel incision and/or widening that is mitigated with bank armoring and/or grade control structures.

Recovery potential

The recovery potential metric rates the ability of the river system to recover from major disturbance. The predominant factors are (1) whether the river has a sufficiently-wide floodplain and channel migration zone within which it can move and adjust unimpeded by artificial structure, and (2) whether the riparian zone is in sufficiently good condition to support rapid natural vegetation recovery. Sub-reach grades have a wider range, from A- to F- (Tables 4.8a and b). Failing grades indicate sub-reaches that depend entirely on artificial stabilization, engineered structures, or routine maintenance to maintain functional condition, and have no capacity to recover naturally if these fail. In these areas, severe infrastructure damage or safety risks are often the probable consequences of bank failure. A serviceable channel migration zone and the potential for natural channel recovery are virtually nonexistent on these segments.

Scores in the C to D range indicate some potential for recovering function after disturbance, but direct intervention would probably be needed for recovery to occur in a reasonable amount of time. These river segments have significantly diminished channel migration zones, obstructions to physical movement and adjustment, and limited vegetation cover due to a lack of local source material, dispersal barriers, impediments to establishment, or presence of exotics. Infrastructure and human safety are at risk in major events. The important factors limiting recovery potential are: encroachment onto floodplains, channel migration zones, and riparian areas by berms, development, and infrastructure. Infrastructure in the river itself such as dams and bridges are particularly influential drivers of river health and the scores for this metric specifically.

Reach-scale grades ranged from C+ to D-, however, it is important to recognize that the major impediments to recovery that result in failing grades occur on short sub-reaches in association with sub-reaches that are less impaired. Since reach scores are calculated as the weighted-average sub-reach scores, the short, high-risk segments are averaged with low-risk segments within a reach, which tempers the grade at the reach scale.

Physical structure

The physical structure indicator ranged from B- to D across the 18 reaches and averaged C to C- across the four zones (Table 4.10). Coarse-scale structure was in poorer condition on most reaches (relative to fine-scale), with grades ranging from B- to F; only one reach was in the B range. Except in two reaches in the Plains zone, fine-scale structure was always at least in the C range and almost half the reaches were in the B range.

Table 4.10: Summary of physical structure indicator scores and grades organized by zones and reaches.

Zone	Canyon			Rural			Urban							Plains				
Reach	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Coarse-scale	76	67	70	78	70	75	59	74	77	73	75	65	77	80	60	73	73	68
Fine-scale	76	80	72	85	74	83	72	80	80	81	87	74	77	72	65	74	75	69
Physical Structure	76	74	71	82	72	79	66	77	79	77	81	70	77	76	63	74	74	69
	74			78			75							72				

Coarse-scale structure

The fundamental shift in river dynamics from alluvial conditions to an artificially-stabilized threshold channel through most of the study area has significant ramifications on coarse-scale physical structure, affecting the diversity of characteristic depth-velocity combinations and physical features. The natural processes that maintain structural diversity on dynamic alluvial rivers such as lateral bend scour, bar deposition, and accumulation of large woody material are rarely present on channelized and artificially-stabilized reaches. Structural diversity on these impacted reaches depends on artificial material and engineered features. Patterns in sub-reach grades for the coarse physical structure metric, which range from A- to F- (Tables 4.8a and b), generally correlate with the degree of channelization, but acute impacts from in-channel dams and diversion weirs are also an important factor. Dams and weirs create flat slack water where sediment accumulates and scour is limited, resulting in structural homogenization at both the coarse and fine scale.

Sub-reaches with failing grades have severely homogenized structure in the form of glide habitat caused by in-line diversions. Sub-reaches scoring in the D range lack some characteristic depth-velocity combinations or structural elements at most flow levels. In most cases, structural homogenization on these segments is caused by artificial stabilization, low scour potential, and lack of large woody material in the river. Despite the widespread impacts of channelization, channel and bed armoring, in-stream structures, and impaired flow regime, some sub-reaches are less impacted and still maintain a high degree of structural diversity due to natural or artificial mechanisms. Less developed segments in between diversions in the upper part of the Rural zone have highly functional coarse physical structure grades in the B range. Even in the Urban and Plains zones at Lee Martinez Park and the ELC, for instance, some sub-reaches were graded in the B range. Reach-scale scores range from B- to F+, reflecting the average of several more diverse sub-reaches within each reach.

Fine-scale structure

Fine-scale structure grades are based primarily on streambed characteristics at a scale relevant to aquatic insects and larval fish. The predominant factor is availability of interstitial space within bed material, which may be reduced by bed armoring, embeddedness, fine sediment accumulation, or excessive algae growth which are primarily caused by a decreased frequency of flushing flows (Figure 4.12). Grades were similar to coarse-scale grades because the same types of stressors affect them both. Fine structure sub-reach grades ranged from A- to F- (Tables 4.8 a and b).

Figure 4.12: Fine sediment deposited following fires clogs spaces between the cobbles. This eliminates important habitat for aquatic insects and spawning fish (left). Team member Johannes Beeby reaches down to check the embeddedness of cobble while scoring the fine scale metric.

As with coarse-scale structure indicators, failing grades were assigned to flat sub-reaches just upstream of diversion dams and bridge constrictions that form backwater conditions at high flow. On these segments, the bed is static and armored or embedded with fine sediment or algae. There is little to no available interstitial space. Clean and unarmored sub-reaches exist throughout the study area where the river is unaffected by in-stream structures. The 2013 flood, followed by several years with above-average peak flows, may affect the interpretation of results based on field observations for this metric. Flows during these events appear to have been high enough to mobilize coarser bed material and flush fines from the majority of riffles. These observations confirm that bed mobility and bed flushing functions are still intact, to varying degrees, along most reaches of the Poudre, justifying a range of scores in the B to C range for reaches that are not highly impacted by in-stream structures or dams.

Aquatic Life

Aquatic life indicator scores ranged from B- to C, with roughly one-half of the reaches in the B range (Table 4.11). Surprisingly, three reaches in the Urban and Plains zones received higher grades for aquatic life than three of the Canyon zone reaches; however, the overall aquatic life scores from the Canyon zone were higher than the Urban zone. In the majority of stream reaches, breaks in habitat are caused by cross-channel structures severely impact the aquatic habitat connectivity grades. Habitat segmentation caused by these structures is the main cause for the depression of aquatic life scores in the Canyon zone. The lack of cross-channel structures improved habitat connectivity in the downstream portion of the Urban zone and within the Plains zone. While the ability to support a fishery is a critical and highly valued aspect of the river, it was important to represent available data accurately without introducing additional uncertainty. Because fish sampling data are infrequent and conditions of the river can be variable, it was decided to not extrapolate fish sampling data between sampling stations for this baseline assessment. Therefore**, information and grades for native fish and trout were included in the SOPR, but they were not factored into the overall indicator score.**

Table 4.11: Summary of aquatic life indicator scores and grades organized by zones and reaches.

Zone	**Canyon**			**Rural**			**Urban**							**Plains**				
Reach	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
Aquatic Insects	85	85	88	85	85	85	85	85	78	78	85	85	85	85	85	75	75	75
Habitat Connectivity	61	71	55	55	55	55	59	61	59	64	65	65	85	85	85	85	85	85
Native Fish										65			75	55		65		70
Trout	85								95									
Aquatic Life	80	81	78	76	76	76	77	78	72	74	79	79	85	85	85	78	78	78
	80			76			78							80				

Aquatic insects

Aquatic insects can be impacted by a wide range of anthropogenic activities. These organisms are particularly sensitive to changes in water quality and habitat modifications such as increases in fine sediment and algal growth. As the aquatic insect community responds to certain impacts, other aquatic life (such as fish) may also be influenced. To provide an assessment of impacts from stressors, this study considered six sub-metrics, each representing a different aspect of aquatic insect community structure and function. Index scores for the six sub-metrics at the 13 sample stations are shown in Table 4.12, along with the aquatic insect grades for each stream reach. Index scores are measured on a scale of 0 to 100; however, **these values do not do not relate to the academic grading scale**. Index scores are translated into health grades in a separate step.

Stream reaches with high aquatic insect grades generally supported a well-balanced and diverse insect community that included a variety of sensitive taxa. Aquatic insect grades ranged from B+ to C throughout the study area, and most reaches scored in the B range (Table 4.12). The highest grades (A- to B+) were assigned to the Canyon zone (and upstream), and these scores were an indication that the aquatic conditions support a healthy benthic macroinvertebrate community. The lowest scores were produced in reaches 9 and 10 in the Urban zone (78) and reaches 16-18 in the Plains zone (75). Although these scores were somewhat lower than the rest of the study area, results from the six sub-metrics suggest that aquatic conditions support adequate community structure, including some taxa that are considered sensitive to stress. An evaluation of each sub-metric has been included to provide a more thorough evaluation of the macroinvertebrate communities in each sampling reach.

Table 4.12: Index scores (MMI) for the six sub-metrics aquatic insect at the 13 sample stations along with the grades for each reach. A map of these sampling locations is presented in Appendix C).

Zone	Upstream			Canyon			Rural			Urban								Plains				
Reach	N/A			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Sample Station	PRbRB	PRbLSF	PRabvMD	PRabvNF	PRbNF	PRbPWC	PRbHSC		PRaLP		PRabvSSB	PRaLM		PLINC			PROS		PBOX		
EP Taxa	100	100	100	100	100	100	100		100		100	100		100			92		81		
% Chironomidae	88	73	81	89	80	81	72		67		71	48		62			70		55		
% Sensitive Families	16	34	49	32	46	46	46		21		44	11		81			47		19		
Predator/Shredder Taxa	71	79	86	93	64	71	71		64		71	71		50			57		36		
Clinger Taxa	100	100	100	100	100	100	100		100		100	100		100			100		100		
% Non-Insect Taxa	44	71	69	62	59	67	78		76		63	59		41			70		56		
MMI	70	76	81	79	75	78	69		71		75	63		72			73		58		
Aquatic Insects Metric Score	85	85	92	88	85	88	85	85	85	85	85	78	78	85	85	85	85	85	75	75	75
	N/A			80			76			78							80				

EP Taxa *(Mayflies and stoneflies)*

The EP Taxa metric measures community richness based on the presence or absence of Ephemeroptera and Plecoptera (mayfly and stonefly, respectively) taxa, two insect orders that are sensitive to a variety of human-induced changes in water quality and habitat (Figure 4.13). All of the sites in the Canyon, Rural, and Urban zones received a score of 100 from this sub-metric suggesting that mayfly and stonefly taxa were well-represented at each sampling station (Table 4.12) A decrease in sensitive taxa was observed in the Plains zone which may have been an indication that impacts were increasing downstream from Prospect Avenue; however, the decrease in EP Taxa scores exhibited at sites PROS and PBOX were relatively minor and a variety of other sensitive taxa continued to exist at these sites in the Plains zone.

Figure 4.13: A common species of stonefly (*Claassenia sabulosa*), represented one of the sensitive taxa measured with the EP Taxa sub-metric within the Cache la Poudre River.

Percent Chironomidae *(non-biting midges)*

The Percent Chironomidae sub-metric measures the relative abundance of the family Chironomidae (non-biting midges). Chironomidae are typically considered more tolerant to changes in aquatic conditions than other insect taxa, so changes in the proportion of Chironomidae can be a good indicator of stress. The Percent Chironomidae sub-metric is sensitive to a variety of potential stressors including increased nutrients. Scores from this metric were somewhat variable within the study area; however, there appeared to be a slight increase in stress (represented by lower scores) at most sites in the Rural, Urban, and Plains zones. The highest proportion of non-biting midges were found at the farthest downstream site (PBOX) in the Plains zone which produced the lowest Percent Chironomidae score (55). As with the EP Taxa sub-metric, these results suggest that macroinvertebrate communities have been somewhat disturbed in areas of the river near urban areas.

Sensitive Plains Families

The Sensitive Plains Families sub-metric was designed by the CDPHE specifically for Colorado plains streams. It is a general measure of aquatic condition based on the presence or absence of key taxa that are known to occur in lower elevation Colorado streams (Figure 4.14). Results from this sub-metric produced scores ranging from 11 at site PRaLM to 81 at site PLINC – both stations are in the Urban zone. This sub-metric is a CDPHE regulatory requirement; however, it is possibly biased at high elevations since the natural range of many of the indicator taxa does not extend beyond the plains. Because of these limitations, the low scores produced at higher elevation sites may not be indicative of poor aquatic conditions. On the other hand, the lower scores for the Sensitive Plains Families in the Urban and Plains zones probably detect real health impairment caused by land use and management.

Figure 4.14: A mayfly (*Leptophlebia cupida*) that is a representative from one of the Sensitive Plains Families (Leptophlebiidae).

Predator and Shredder taxa

The Predator/Shredder Taxa sub-metric measures the abundance of taxa in the predator and shredder feeding (food acquisition) groups. Both predators and shredders are moderately sensitive to ecological disturbances that alter the availability of food in the stream. Results from this sub-metric provide evidence of high numbers (represented by higher scores) of these sensitive taxa within most of the study area with decreasing scores in the lower reaches of the Urban zone and throughout the Plains zone. Like the other sub-metrics, the decrease in the number of predators and shredders within the Urban and Plains zones provides additional evidence that stress has increased in these downstream reaches.

Clinger Taxa

The Clinger Taxa sub-metric measures the number of insect taxa that cling to clean substrate surfaces in riffle habitat (Figure 4.15). These taxa are often reduced when the natural substrate material becomes embedded or covered by fine sediment or algae. All the sample sites in the study area produced the highest possible score for this sub-metric (100) which showed that clingers are well-represented throughout the entire study area, even in regions that may be susceptible to urban or agricultural runoff.

Figure 4.15: This species of caddisfly (*Brachycentrus americanus*) is an example of a Clinger Taxa.

Percent Non-Insect Taxa

Insects are generally more sensitive to changes in water quality or habitat alterations than non-insects (such as snails, worms, mites, etc.), therefore high proportions of non-insect taxa in benthic communities can be another indicator of stress. Results from this sub-metric showed that the proportions of non-insect taxa were somewhat variable in the study area and the lowest proportions of these taxa (represented by higher scores) were produced at the two sites within the Rural zone. Despite its location upstream the SOPR study area and above most known sources of stress, site PRbRB produced one of the lowest non-insect taxa scores (44) (Table 4.12). The macroinvertebrate community at this location contained a high proportion of aquatic worms belonging to the family Naididae, a group known to be tolerant to nutrients as well as a variety of other aquatic disturbances. It is possible that the high proportion of worms at this site was a response perturbations occurring upstream near the community of Rustic, Colorado. Elevated numbers of Non-Insect Taxa were also observed at site PLINC; however, scores from this sub-metric improved farther downstream in the Plains zone.

Aquatic habitat connectivity

As described previously, the many cross-channel structures present in the SOPR study area severely fragment the aquatic habitat. The longest section of unobstructed flow is about 11 miles. This reach lies between the Timnath Reservoir Inlet Diversion and Greeley Canal No.3 Diversion. With 16 diversion dams in the study area, the majority of reaches scored a D or lower indicating that most unobstructed reaches are less than two miles long. Reaches within the Rural zone scored lowest, with diversion dams blocking fish passage occurring nearly every mile (see Figure 3.1).

Native fish

At least 20 (and likely more) native fish species historically occupied the Urban and Plains zones of the Poudre River (Colorado Parks and Wildlife, Aquatic Research Station, 2016). The loss of more than half the local species over the past 50 or so years is alarming (Figure 4.16). At least four species have not been captured since the mid- to late-20th century and are thought to be locally extirpated. These are the central stoneroller, common shiner, northern plains killifish, and bigmouth shiner. The orange spotted sunfish, red shiner, and brassy minnow have not been observed on the Poudre upstream of I-25 since 2003, 2005, and 2010, respectively, while the creek chub is becoming increasingly rare.

Figure 4.16: The number of native fish species in the Poudre River has steadily declined over time.

In 2015, ten native fish species were captured across the five sampling stations, including creek chub, fathead minnow, Johnny darter, longnose sucker, longnose dace, plains topminnow, sand shiner, and white sucker (Figure 4.17). The plains topminnow has special status in Colorado, where it is listed as a Tier 1 species of greatest conservation need in CPW's State Wildlife Action Plan (Colorado Parks and Wildlife, 2015). Flathead minnow, longnose sucker, and white sucker were captured at all five stations. Longnose dace and green sunfish were found at four of the five stations, Johnny darter at three, plains topminnow and sand shiner at two, and creek chub at just one.

Figure 4.17: The Johnny darter is a small-bodied plains fish that is still present in the Fort Collins reach of the Poudre.

The native fish metric is based on the number of native species still present in sustainable populations, measured as the number of species and number of life stages captured in samples. The number of species, life stages, and corresponding metric grades are shown in Table 4.13. Five reaches were sampled in the Plains and Urban zones, and the number of species present ranged from four to eight, with multiple life stages represented for only about half the species at each site. Consequently, grades ranged from C to F.

Table 4.13: Native fish indicator scores in five reaches of the Poudre River.

Zone	Canyon			Rural			Urban							Plains				
Reach	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Sample Station										P1			C1	P2		P3		P4
Number of Species										6			8	4		6		7
Life Stages										half			half	half		half		half
Native Fish										65			75	55		65		70

The disappearance of native fish parallels fundamental changes in the river system and is, therefore, a powerful indicator of the degree of biological impairment. The most likely stressors contributing to this negative trend in species diversity are de-watering (impaired base flow regime), habitat fragmentation from man-made barriers to fish migration (*i.e.,* aquatic habitat connectivity impairment), decreased habitat complexity (*i.e.,* physical structure impairment), altered temperature regime (*i.e.,* water quality impairment), and competition with non-native species. Even temporary degradation of habitat conditions can have permanent or long-term effects on native fish because when a reach becomes uninhabitable, even for a short time, it is often improbable or impossible for them to return owing to the numerous fish migration barriers.

Native fish diversity tends to be correlated with local habitat complexity; however, there is a larger landscape-scale trend of extirpation. Fish species are disappearing from the river altogether as their longitudinal range shrinks. The red shiner and bigmouth shiner were previously detected in the Plains zone, but are now found only east of I-25. In addition to the species already extirpated from the study area, the plains topminnow's range appears to be contracting upstream since it was found only at the two most upstream sampling stations. The sand shiner was found only at the two downstream stations, and its range appears to be contracting downstream.

Trout

Brown trout are not native to the Poudre River, but the species has become dominant on most Colorado Front Range rivers including the Poudre. It is a valued game fish and also a common biological indicator of aquatic habitat conditions. Trout populations were sampled at two stations in the study area in 2015, and data were used to grade the trout metric for the two reaches represented (Figure 4.18).

The uppermost reach of the Canyon zone, between Munroe Diversion and the North Fork was graded B for brown trout. Multiple-age classes and a high-biomass estimate indicate a naturally-sustaining population with high biomass. While there are high densities of brown trout, a large proportion of them are below quality-size (*i.e.,* less than nine inches), in the six - nine inch range and with a below-average relative weight. These characteristics brought down the overall reach score. Population estimate data suggests 436 brown trout per mile greater that are quality-size or greater. This is considered a moderate or mediocre recreational fishery.

Figure 4.18: Brown trout thrives in much of the study area (photograph courtesy of Colorado Parks and Wildlife).

The reach between Shields Street and College Avenue in the Urban zone was graded A, due to age class diversity as well as high biomass and population estimates. Multiple age classes, high recruitment level, and high numbers of adult fish indicate a well-supported and natural- sustaining trout population. Population estimates suggest 625 quality-size fish per mile and biomass; this exceeds “gold medal” standards for trout, indicating a viable recreational fishery and good support of faunal food webs (Figure 4.19). Results for the six sub-metrics are detailed in Table 4.14.

Table 4.14: Trout indicator scores in two reaches of the Poudre River.

Zone	**Canyon**	**Urban**
Reach	**1. Munroe to North Fork**	**9. Shields to College**
Sample Station	Gateway Park	Lee Martinez Park
Age classes	> 4 age classes	> 4 age classes
Recruitment	Low (600 age-0 trout/mile)	High (1100 age-0 trout/mile)
Recreation potential	Moderate (360 quality trout/mile)	High (590 quality trout/mile)
Relative weight	Below average (0.86)	Average (0.94)
Biomass	69 lb/acre	73 lb/acre
Population number	High 1430 stock size trout/mile	High 792 stock size trout/mile
Trout Metric	**85**	**95**

Trout populations are sensitive to a suite of stressors. Common factors limiting trout populations on the Poudre include poor coarse physical habitat diversity, water quality (especially temperature regime and dissolved oxygen), critically low flows during summer and winter, seasonal dry-ups, and migration barriers. Healthy, naturally-sustaining trout populations (at least for the short term) indicate that none of these factors are currently critical on the two reaches that were sampled. The exceptional trout population in the Urban zone in 2015 is partially due to several years in a row of higher-than average flow. A self-sustaining population of trout on this historically warm-water reach, combined with the evidence of declining native warm-water fish species, suggests that the current water temperature regime is cooler than it was historically, but it is difficult to tease apart all the factors affecting temperature and fish populations.

Figure 4.19: Osprey live and hunt along the Poudre River and rely on fish and a central food source.

5 River health scores and key issues by zone

5.1 Overview of Poudre River health

Land-use changes in the Poudre River corridor have been pervasive since European settlement in the middle 1800's. The once-broad and complex river-riparian corridor on the plains has been dramatically narrowed and simplified. We will never know exactly what the Poudre looked like before these lands were settled (Figure 5.1). Even by the time the town of Fort Collins was established around 1870, more than a decade of farming and ranching had occurred in the area, and nearly 30 years before that, the fur trade had essentially extirpated beavers from the region. Today, no part of the river system remains untouched. The river is channelized, confined, and armored for much of its length, and flows are heavily managed to meet water-use needs. Much of the historic riparian zone and floodplain has been developed or converted to other land uses.

Figure 5.1: *On the Cache la Poudre River*, painted by Worthington Whittredge in 1876, is the earliest depiction of the Poudre River on the plains that we have. Farming and ranching land uses had already been established for decades by this time, and the river and riparian zone appear to be already impacted through clearing of the understory. Conversely the canopy was sparser historically, as this painting depicts the river before exotic trees such as crack willow invaded and crowed the canopy.

And yet, all things considered, the Poudre is still a relatively healthy and resilient river. Overall, this assessment gives it a C rating, meaning that it is functionally healthy. The river still supports the basic natural river and riparian functions—even through the Urban zone—despite a suite of ecological stressors that affect all aspects of river health.

The SOPR is a baseline against which the City can measure progress towards its vision of "…*sustaining a healthy and resilient Cache la Poudre River"*. The health assessment scores (Section 4) reveal the ramifications that stressors (described in Section 3) have on ecosystem condition and the degree of impairment observed in each zone and reach. Here in Section 5, the focus shifts to an overview of river health, describing the link between stressors and impairment for each of the four zones. Poudre River health indicator grades for each zone are compared to the ranges recommended by river experts and resource managers—as described in the Poudre RHAF—to highlight best and the most impaired aspects of river health. This section also includes an analysis of the causes of impairment and reveals which problems may be practically solved.

Patterns of land and water use vary across the four zones, but the most influential stressors are consistent throughout the study area. To provide a succinct summary of key issues that affect modern-day river health, Table 5.1 provides a matrix illustrating the relative contribution of each stressor on each indicator. The City has influence over some of these stressors—and therefore an opportunity to improve river conditions—and less or no influence over others. This section describes the general approaches the City could take towards improving river health based on a summary of conditions for each of the four zones. This report, however, does not make recommendations for specific projects or actions to manage factors that contribute to river health, as these decisions must involve the broader set of stakeholders.

For this chapter, the summaries of river health by zone are organized generally by indicators or groups of indicators that are related (for example, floodplain extent and the riparian condition indicators can be discussed together.

Table 5.1: Matrix that relates the causes of impairment (stressors) on the vertical axis with the degree of impairment (indicator scores) on the horizontal axis. The degree of impairment is based on a high, medium, and low scale (dark grey to light grey, respectively).

Poudre River Stressor Matrix

Stressors	Flow Regime	Sediment Regime	Water Quality	Floodplain Connectivity	Riparian Condition	River Form	Resilience	Physical Structure	Aquatic Life	River Health
Diversions (withdrawals)	■	▒	▒	▒	▒	░	░	■	■	■
Transbasin diversions (augmentation)	░	░	░		░	░			░	░
Large dams/reservoirs	■	■	▒	░	░	░	░	■	▒	■
Wildfire/burn scars	░	░	▒						░	░
Channel erosion		░								░
Impervious surfaces/urban stormwater runoff	░	▒	▒		░				▒	▒
Irrigation runoff/return flows	░		░						░	░
Wastewater effluent	░		■		░				▒	▒
Buildings and roads				▒	▒	░	▒			▒
Rural/agricultural land use			░	░	▒					░
Open space and parks			░		░		░			░
Gravel pit/ponds	░		░	■	■		▒			▒
River crossings		░		░	▒	▒	▒	■	░	▒
Berms/channelization		░		■	■	■	■	▒		■
Bank/channel armor		▒		▒	■	■	▒	░	▒	■
Channel structures		▒		░		▒	▒	■	■	▒
Woody material recruitment/removal						░		▒	▒	░
Exotic plant species/weeds					▒					░

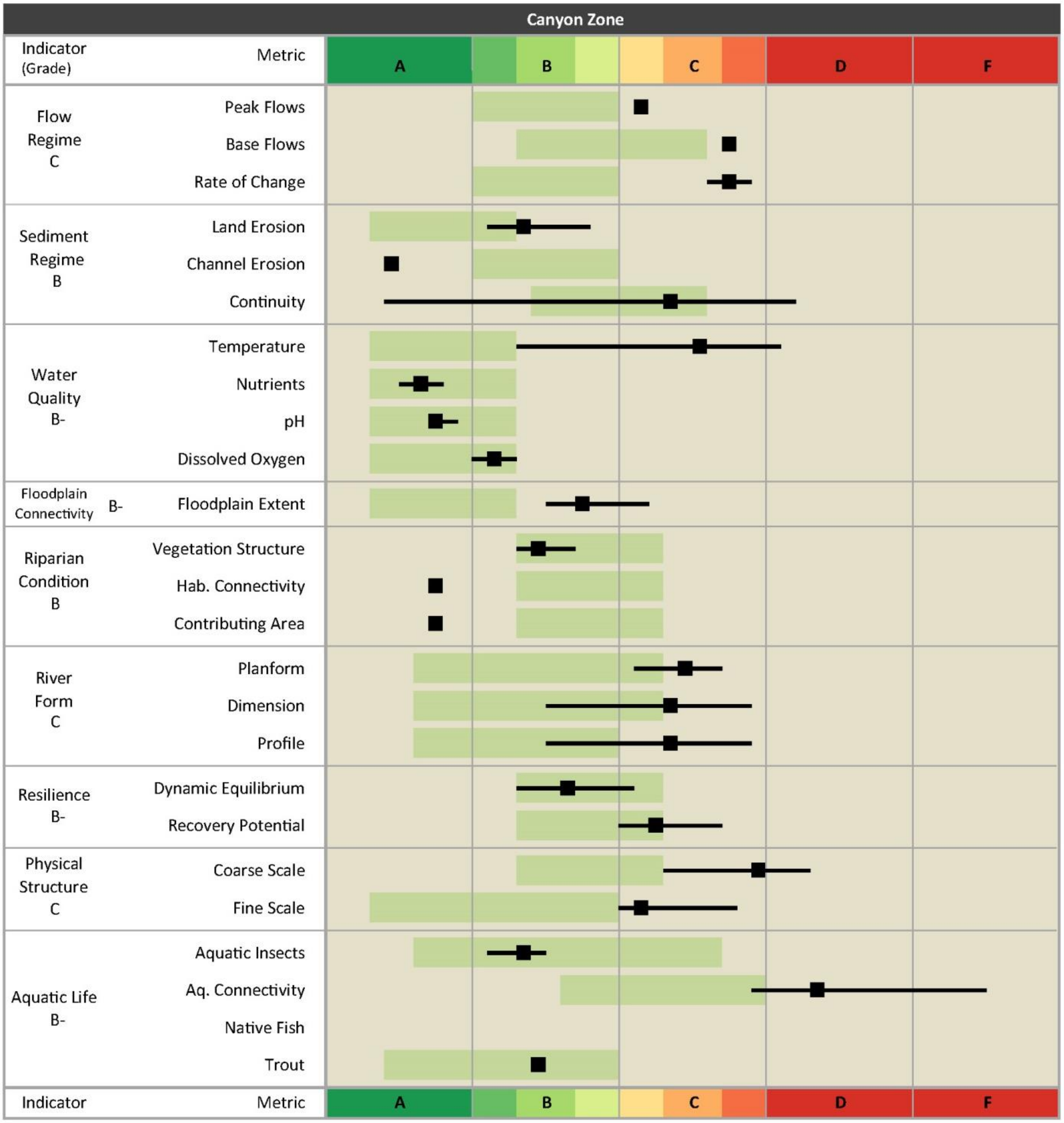
■	▒	░
High	Med	Low

5.2 Canyon zone

Figure 5.2: In the Canyon zone, the river is bounded by a narrow floodplain and confined between steep canyon walls, rocky hills and/or the CO Highway 14.

Geology governs the character of the Canyon zone. Relatively steep and straight, the river is bounded by a narrow floodplain and riparian corridor that is confined between steep canyon walls and rocky hills (Figure 5.2). The influence of peak flows on the floodplain is therefore limited, and naturally-resistant rock banks are insensitive to the rushing waters. A narrow band of riparian vegetation provides wildlife habitat and a critical migration corridor. The forested watershed is mostly undeveloped, and to a large extent, its natural hydrologic, geomorphic, and biogeochemical processes are intact, providing support for river health (Table 5.2).

Table 5.2: Metric grades in relation to recommended ranges for the Canyon zone. Recommended ranges (green bars) represent expert opinion for reasonable and practical potential metric grades given existing land and water-use constraints. Points (square black boxes) present the average grade for the given metric for this zone. The black lines show the range of results across the reaches within this zone.



Flow regime scores are below recommended ranges for all three metrics on the Canyon zone, suggesting some room for improvement in peak flow, base flow, and rate of change, albeit the concerns are less than the downstream zones. Cumulative impacts from within the watershed and various dams are responsible for some of the alterations to flow regime, but flows are most directly impacted by diversions that occur within this zone. The scores for all three metrics are closely linked to the magnitude and timing of diversions, storage, and releases.

The overwhelming sediment regime stressors are the large dams that interrupt sediment continuity, so scores for the continuity metric fall below the recommended range downstream of the North Fork confluence. The land-erosion metric scored slightly below the recommended range due to the impacts from recent fires, and this score will improve as the burn scars revegetate. In addition, the Coalition for the Poudre River Watershed and several stakeholder groups, including the City of Fort Collins Utilities, have developed an Upper Poudre Resilience Watershed Plan. The purpose of the plan is to improve watershed resilience through watershed restoration activities aimed to reduce risk of future wildfires and post-fire erosion (Figure 5.3).

Figure 5.3: Post-fire land erosion causing a major debris flow into the Poudre near the upper Landing Campground.

The channel erosion metric for the sediment indicator was above the recommended range. In the Canyon zone channel erosion is altered by riprap banks along Highway 14. However, sediment supply from bank erosion would naturally be limited in this confined canyon setting.

Water quality

Nutrient, pH, and dissolved oxygen scores in the Canyon zone fell within recommended ranges. Water temperature is within range upstream of the North Fork confluence, but fell to D+ immediately downstream due to seasonal regulatory standards exceedances. The D+ grade may overestimate the degree of temperature impairment, however, since exceedances are rare and limited to shoulder seasons (see Section 4, water quality subsection). The City's monitoring data do confirm that temperatures on the North Fork are generally warmer than the mainstem between April and November, however. This may be because the North Fork basin is a naturally warmer habitat, or it could be an effect of Seaman Reservoir. The direct influence of Seaman Reservoir on water temperatures is not straightforward. A review of temperature data collected through the City of Fort Collins cooperative monitoring program shows that the reservoir can have both warming or cooling effects on the North Fork, most likely depending on the timing, volume, and nature of reservoir releases. Whether releases are made from the spillway or bottom outlet is of particular importance. The somewhat warmer temperatures downstream of the confluence likely result from combination of natural and anthropogenic factors.

River channel *(river form, resilience and physical structure indicators)*

Most of the physical geomorphic metric scores in the Canyon zone are below recommended ranges, suggesting the potential for improvement, but this may be misleading since early estimates for these metrics in the original RHAF underestimated the degree of impairment to floodplain connectivity, river form, resilience, and physical structure. The original estimates of current condition presented in the RHAF for these metrics are in the A to B range, but measured results are from B- to C. Localized impacts at diversion dams and bridges account for some of the physical river channel impairment, but the primary cause is Highway 14, which runs up the narrow canyon parallel to the river. Portions of the road are built on fill that encroaches on the already-limited floodplain area. Areas where road fill impinges on the river are physically stabilized using bank armor, which itself is a source of impairment to physical structure. Armored reaches have proven resistant to damage from floods, but considerable damage would occur and there would be limited potential for unassisted recovery if or when these banks do fail.

Riparian corridor *(floodplain connectivity and riparian condition indicators)*

The Canyon zone was graded B for riparian condition and floodplain connectivity, reflecting the highly functioning nature of the streamside habitat. All of the riparian condition metrics were at or above recommended ranges. The recommended range for floodplain connectivity from A to B+ is greater than the observed grades (B to C+) indicating that the effects of Highway 14 encroachment and diversion dams are greater than previously estimated. Highway 14 is the sole source of impairment to riparian zone health on most of the canyon reaches, and scores generally correlate with the degree to which the highway encroaches on the floodplain and riparian zone. Outside of the influence of the road, such as on the opposite bank of the river, riparian zone habitat is essentially in natural condition. Most of the reach is managed for natural habitat and other than the highway, there are few artificial barriers to the movement of organisms through and between riparian habitats. As with habitat connectivity, the contributing area surrounding the Canyon zone is in very good condition and managed primarily as wildland by federal, state, city, and county agencies.

Aquatic life

The aquatic insect indicator results provide strong evidence of healthy and functional aquatic fauna communities in the Canyon zone. While grades ranged from B to B+, individual metric values were well within the recommended ranges, and scores for all three sampling sites were among the highest within the study area. High scores for the EP taxa and clinger taxa sub-metrics show that the zone supports insect taxa that are considered sensitive to a variety of perturbations. The only evidence of minor stress in this zone was provided by the percent of non-biting midges (Chironomidae) and non-insect taxa that known to be more tolerant of poor water quality. The zone also supports a relatively healthy trout population and a viable trout fishery, at least on the sampled reach above the North Fork. However, aquatic habitat connectivity is severely limited in the zone due to the frequency of major structural barriers with metric grades from C- to F. The recommended range for this metric (B to C-) would be realistic only if instream barriers could be removed or reconfigured.

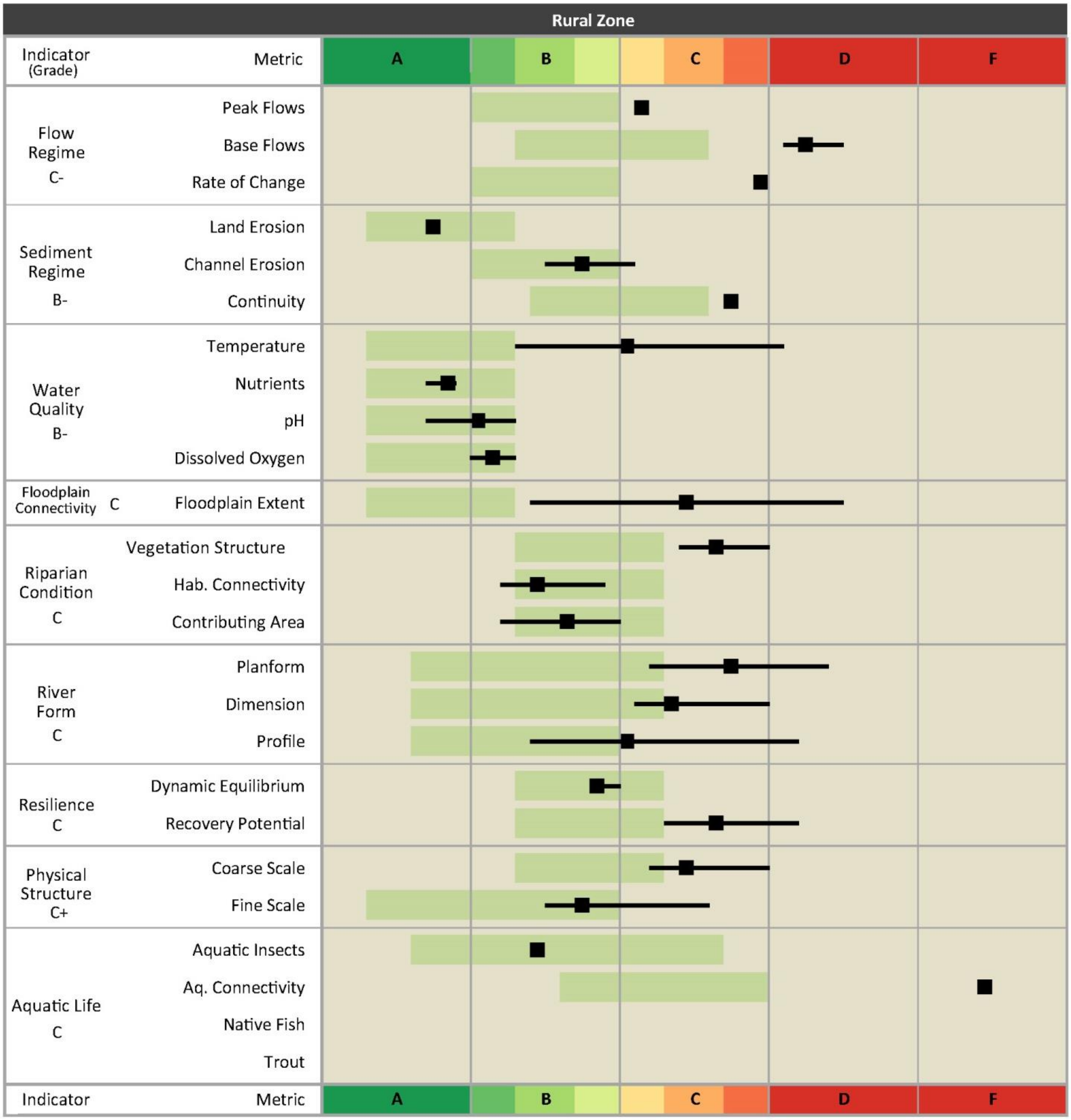
Figure 5.3: In the Canyon zone the confluence of the North Fork (the largest tributary in the canyon) into the main stem at Gateway Natural Area influences water quality parameters and therrefor habitat foraquatic wildlife.

5.3 Rural zone

Figure 5.4: As the river exits the canyon, the gradient begins to slacken, and the native river type shifts to a meandering channel that maintains form and structure through dynamic equilibrium between erosion and sediment supply.

The Poudre transitions from a confined to an unconfined river in the Rural zone, which is a fundamental shift in geomorphic river type (Figure 5.4). In the unconfined reaches downstream of the canyon, the floodplain and riparian zones become critical drivers of river health. Lacking resistant geology, a functional floodplain would be able to dissipate flood waters and their potentially destructive energies. Riparian vegetation provides roughness, which slows flows while lending structural integrity to river banks, serving as important wildlife habitat, and acting as the source of organic material that forms the base of the aquatic food chain. The gradient begins to slacken in this zone, and the native river type shifts to a meandering channel that maintains form and structure through dynamic equilibrium between erosion and sediment supply Figure 5.4). The Rural zone is still classified as cold-water river, with water temperature standards based on the requirements for supporting trout. The Rural zone is where land use shifts from wildland to rural development, and agriculture, eventually phasing into urban development (Table 5.3).

Table 5.3: Metric grades in relation to recommended ranges for the Rural zone. Recommended ranges (green bars) represent expert opinion for reasonable and practical potential metric grades given existing land and water-use constraints. Points (square black boxes) present the average grade for the given metric for this zone. The black lines show the range of results across the reaches within this zone.



Flow and sediment

All the flow regime metrics scored well below recommended ranges in the Rural zone, with diversions being the greatest cause of impairment. The effects of large reservoirs on reduced peak flows may still be a factor on these reaches, but the direct effects of water management have the greatest influence on flow regime scores. The base flow and rate of change metrics are much more impaired than peak flows. Recommended ranges for these metrics of B to C and B+ to B-, respectively, may not be obtainable unless there is willing collaboration and agreements can be made to manage water diversions differently. The cumulative effect of numerous diversions reduce, peak flows with in this zone. Similarly, base flows are also effected with the Greeley Filter Plant, Little Cache, and Watson Lake diversions all known to cause winter dry-ups. Some flow augmentation at the Hansen Supply Canal can partially offset the withdrawals but the acute impacts to base flow and rate of change are dependent on the timing of these diversions and releases.

The sediment regime indictor scored a B- in the Rural zone. Land erosion grades fell within the recommended range as impacts from the wildfires diminish moving downstream. The channel erosion metric dropped below the recommend range to a C+ below Rist Canyon Road. Bank armoring within this reach is limiting natural bank erosion processes which contribute to sediment supply imbalance. This altered sediment supply can also create accelerated bank erosion in areas without riprap due to the river's increased capacity to transport sediment. Sediment continuity grades fell below the recommended range in this zone reflecting the lingering impacts from the dams in the contributing watershed and, to a lesser degree, the smaller in-line dams within the zone.

Water quality

Water quality in the Rural zone is similar to that of the Canyon zone, with nutrient, pH, and dissolved oxygen grades within recommended ranges and temperature falling short. The reaches that score low for temperature are in the upper portion of the zone, and the degree and causes of impairment are similar to the reaches in the Canyon zone. Temperature grades increase rapidly through the zone. The sudden improvement is due to the fact that the lower reaches in this zone do not exceed temperature standards. This may be due, in part, to the introduction of cold water effluent from Horsetooth Reservoir via the Hansen Supply Canal. While these inflows may offset some of the warming observed in the Canyon zone downstream of the North Fork, the cooler stream temperatures may affect assemblages of fish and other aquatic organisms, both locally and downstream. However there are no fish data for the study period (2015/2016) in this zone and the relatively high aquatic insect scores reflect thresholds set for cooler waters.

River channel *(river form, resilience and physical structure indicators)*

Channelization, berms, armor, diversion dam structures, and bridges have a strong negative influence on floodplain connectivity, river form, resilience, and physical structure through the Rural zone. The effects of these stressors are very localized, but they are so widespread that most of the river channel indicators show impairment through the zone. A few segments, however, display a more natural form and variation where the river has not been contained or confined. In these segments, natural floodplains still exist and the river is not as constrained or entrenched, though nowhere are they wide enough to meet the target range for the metric. Consequently, the river has been able to adjust its form to changing sediment and flow regimes and maintain a more natural form that is appropriate for the landscape position. As a result, net dynamic equilibrium scores are within the recommended range. The recovery potential metric scored well below the recommended range, however. Dams, bridges, berms, armored banks, and other confining structures on the reach increase the risk of damage and severely limit the river's ability to recover from large to moderate flood events.

Coarse-scale structure, such as overhanging banks and a mosaic of complex aquatic habitat, has suffered in the Rural zone with the installation of bank armoring and other active channel modifications. Even though some of the better pool-riffle sequencing was found in this zone, it is still lacking in pool habitat and structural diversity. The Rural zone scored best for fine-scale physical structure because of the recent occurrence of flushing flows on bed mobility, and most of the reaches are within the target range for this metric.

Riparian corridor *(floodplain connectivity and riparian condition indicators)*

Floodplain extent is well below the range recommended for river health in the Rural zone, and this is mostly the result of channelization, berms, and other direct physical impacts. Low-impact land uses dominate the historical floodplain area and SOPR riparian zone (defined as the corridor 100m from either bank). Today's riparian zone is largely functional owing to the lack of widespread or intensive development and relatively low presence of problematic woody species. Overall, riparian condition in the Rural zone rated a C. This grade accurately reflects the functional ability of the riparian habitats to support river health, and, in turn, the ability of the rural landscape to support somewhat healthy riparian habitat, while acknowledging that land use and land cover changes have substantially altered the form, structure, functioning and ecological integrity of the riparian habitats. The vegetation structure and complexity metric was the only riparian metric below the recommended range. The lower-than-desirable grade stems from the fact that much of the riparian zone vegetation has been cleared for agriculture or is no longer hydrologically connected to the river. Two large gravel ponds also severely impair riparian condition on one of the reaches. Sections of roadway affect small portions of the riparian zone, and in the town of Laporte, residential development and Cache la Poudre schools intrude into the riparian zone. The Watson Lake Fish Hatchery is another significant development limiting the riparian zone function.

The habitat connectivity scores are generally good throughout the Rural zone. Each reach had some disruption in the continuity of riparian habitat, such as intrusion of roads, or urban development. The most widespread impact on habitat connectivity is forest clearing for agriculture. Cleared areas still allow passage of most organisms, but cleared habitats are more difficult or dangerous for many organisms to cross, exposing them to an increased risk of predation or heat stress, for example. The contributing area metric indicates that the land use beyond the riparian zone is generally supportive of river health. Widespread light agriculture and small areas of intensive agriculture impair some of the ability of these areas to support river health, but nevertheless most of the contributing area is vegetated and only sparsely developed.

Aquatic life

Aquatic insect grades indicate that the level of stress to aquatic life may have increased slightly in the Rural zone based on minor shifts in the aquatic insect community compared to the Canyon zone. The zone received a C grade which is slightly lower than the grade in the Canyon zone. The EP and clinger taxa sub-metrics reflect healthy aquatic conditions through the zone, however. The number of sensitive taxa remained high in the Rural zone, while the proportion of some aquatic organisms that are considered tolerant to anthropogenic stressors increased slightly. These findings are likely in part the result of increases in agriculture in the surrounding area.

The Rural zone was not directly sampled for fish populations in 2015 so no grades are presented for this zone; however, it has been frequently sampled in the past. Despite the presence of localized habitat features that can influence trout populations within short sections of river, the overall population can be estimated based on prior sampling, as well as upstream and downstream sample points. These extrapolations suggest that in general the Rural zone supports a thriving trout fishery.

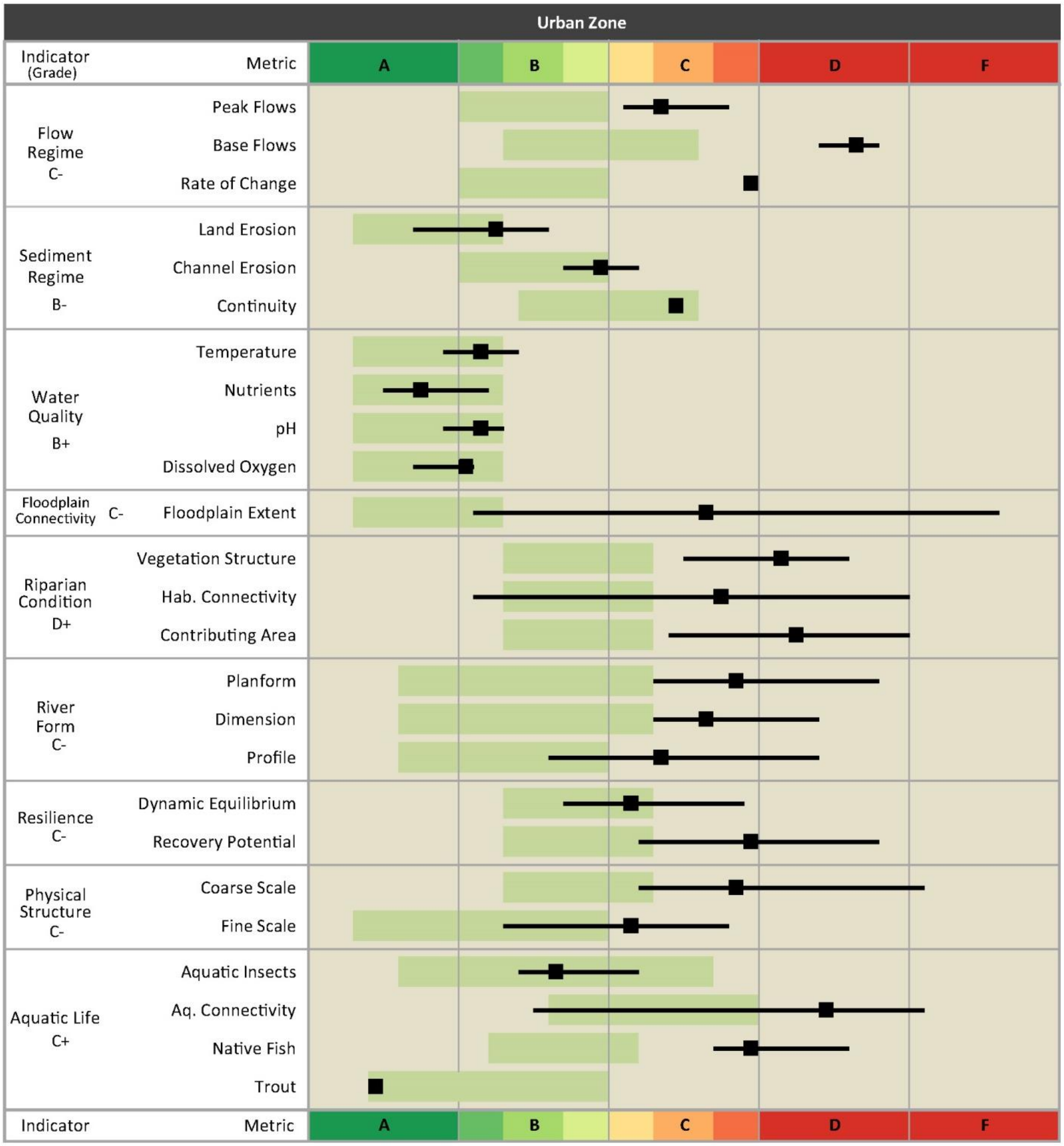
Figure 5.5: In contrast to the foot-long brown trout, the small-bodied longnose dace is one of the few native plains fish that can also survive in slightly cooler waters. It lives in the Poudre all the way up to Gateway.

5.4 Urban zone

As the river courses into and through town, its gradient slackens further and the Poudre begins its transition towards becoming a warm-water river (Figure 5.6). In this zone, the river's natural form would have been multiple channels interwoven into a braided pattern, running through an expansive and unconfined floodplain. Riparian vegetation would have formed a complex mosaic of habitats, providing critical support to river functions and health. Floods and disturbance were historically common and would have shaped most ecosystem processes (Table 5.4).

Figure 5.6: The river takes a narrow course through the heart of the Urban zone where the Linden Street crosses the River.

Table 5.4: Metric grades in relation to recommended ranges for the Urban zone. Recommended ranges (green bars) represent expert opinion for reasonable and practical potential metric grades given existing land and water-use constraints. Points (square black boxes) present the average grade for the given metric for this zone. The black lines show the range of results across the reaches within this zone.



Flow and sediment

The pattern of flow regime impairment in the Urban zone is similar to the Rural zone, but alterations are more pronounced because the diversions and flow reductions are cumulative. Peak flow, base flow, and rate of change metrics are all below the recommended ranges.

The sediment regime score dropped slightly in the Urban zone, but remained at a B- grade. Sediment grades generally decreased moving downstream through the Urban zone as land uses increasingly impact the sediment regime. Land erosion scored an A in the upper reaches of the Urban zone, but fell below the recommended range to a B+ at Shields Street due to increased urbanization and development surrounding the river. Channel erosion scored on the low end of the recommended range in the upper reaches as the river flows through several City owned Natural Areas, but fell below the recommended range to a C+ at College Avenue.

From College Avenue downstream the river becomes heavily impacted by bank armoring and channelization further disrupting natural erosion and deposition processes causing a sediment imbalance.

Figure 5.7: In addition to its construction site sediment and erosion control program, the City's LID Program requires on-site infiltration of stormwater to help prevent in-stream impacts associated with increased imperviousness.

Water quality

Water quality in the Urban zone is quite high, reflecting the quality of water that comes into town from upstream zones, and the City's commitment to protecting water quality in the Poudre River by managing stormwater runoff and meeting regulatory requirements for wastewater effluent. All water quality metrics scored within recommended ranges. Temperature regime grades are high (A- to B+) indicating no excessively warm periods, but the success of coldwater fish and the demise of native warmwater species on this historically warm-water segment may suggest an unnaturally-cold temperature regime—probably due to the release of cold water from Horsetooth Reservoir into the river just upstream at the Hansen Supply Canal.

River channel *(river form, resilience and physical structure indicators)*

The geomorphic (*i.e.,* physical) condition of the Poudre is most compromised in the Urban zone. The majority of the floodplain has been severely encroached upon or cut off by channelization and berms. More than two thirds of the river in this zone is armored and more than half of it is directly affected by eight dams and twelve bridges. These features have severely impacted river form. In most places, the channel is moderately to severely entrenched. Resilience of the system is low in the Urban zone, particularly with regards to natural recovery potential, due to the level of floodplain encroachment and the number of structures. These alterations increase the risk of flood damage, as well. Channel stability depends almost entirely on artificial stabilization. A few areas remain where a wide buffer of undeveloped land has been maintained along the river corridor especially between Shields Street and College Avenue. Most of the undeveloped riparian zone is managed by Fort Collins Natural Areas or the Parks Department (in the case of Lee Martinez Park).

Bed mobilization and flushing functions appear to be intact in portions of the Urban zone that are not affected by dams or bridge constrictions, but these functional segments are short because there are so many such structures along the river in this zone. There is little physical habitat diversity here, and fewer pools except for notably higher scores in reaches 8 and 9 (from Larimer and Weld diversion to College Avenue) where some segments of river adjusted and became more complex during the 2013 flood (*e.g.*, adding large woody material that helped to create pool habitat). Elsewhere, the river is mostly channelized, and large woody material is limited and actively removed from the channel.

Large woody material has many roles in the riverine ecosystem; for example, it is a critical catalyst of habitat structure formation and an important driver of channel form. The systematic removal of large woody material in this zone limits the ability of the river to provide complex habitat and cover for fish, yet this action is deemed essential to public safety and protection of infrastructure. The need for removal of large woody material is an important challenge in the context of urban river management. Increased awareness of the importance of large woody material in river function and health could help instigate creative solutions to its use in future management plans.

Riparian corridor *(floodplain connectivity and riparian condition indicators)*

Overall, riparian condition in the Urban zone scored a D+. While lower than optimal, there is still some positive health support provided by the remaining habitat, such as flood flow abatement, bank stabilization and overall support of resiliency. Starting at Overland Trail the river undergoes a transformation as it meanders through town. In the uppermost reach—from Overland Trail Road to the Larimer-Weld Diversion—ponds from gravel mining, and associated berms, press almost to the banks of the river in spots. The riparian zone on averaged rated a D in the upper reach. The density of gravel ponds gradually decreases going downstream from the Larimer-Weld Diversion. Further downstream, an increasing amount of the riparian zone is City of Fort Collins property managed by the Natural Areas program. Several former gravel pond sites have been restored as wetland and reconnected to the river, allowing the wetland to directly support river health. Downstream of Shields Street, much of the riparian zone is managed by Natural Areas, and much of the zone remains forested, despite the otherwise urban surroundings. Therefore, in the Urban zone, patches of riparian forest in relatively good health and rated grades as high as B or B+, but too little remains across the zone for it to support the functionality recommended to maintain river health.

The reach below College Avenue is the heart of the river's urban course, and width of the riparian vegetation reduces down to a narrow stream-side band. Commercial and industrial areas encroach on the northern riparian zone, but fortunately, much of the riparian zone of this reach is managed by

Natural Areas. Because of that, despite its highly-urban setting, the riparian zone still remains functional. The newly completed Woodward-Governor site on the east bank of the river includes some habitat restoration. At the time of this survey, vegetation development at this site was rudimentary because of its newness, but as the site develops riparian health is expected to substantially increase.

Within the Urban zone, habitat connectivity varies widely according to the diversity of land uses through which the river flows. At the upper end of the zone, habitat connectivity was severely restricted by past and present gravel mining and the loss of vegetated habitat. Habitat connectivity improves downstream of Taft Hill Road, but in the central urban reaches (reaches 10 and 11), habitat connectivity becomes greatly impaired. Fortunately, there is almost always some vegetation or habitat, at least along the banks, providing limited cover for wildlife passage. From Mulberry Street to the end of the Urban zone, habitat connectivity once again improves as more and more of the riparian zone falls under City ownership and Natural Areas management (Figure 5.8). Much of the contributing area of this zone is urbanized or used for gravel mining and water storage. Only in the middle reaches from Taft Hill Road to College Avenue was the contributing area functional in supporting river health. Elsewhere, most land use in the area assess for the contributing area metric have negative effects on river health. Even so the influences are not as negative as might be expected in an area as developed as the City of Fort Collins.

Figure 5.8 At the lower end to the Urban zone the river is bordered on its northern side by industrial development along Mulberry Avenue, while on its south side the floodplain begins to open up as the land is owned by the City's Natural Areas Department.

Aquatic life

The overall health of aquatic insect communities in the Urban zone appeared to be similar to the Rural zone; although, some of the submetrics detected clear changes in community structure. The SOPR assessment assigned a C grade for aquatic life in the Urban zone. Sub-metrics varied in their ability to detect stress in this stream segment, but the richness of sensitive and specialized insect taxa (demonstrated by the EP Taxa and Clinger Taxa sub-metrics) remained high in the Urban zone even though there stressors were generally more severe as a result of increased anthropogenic activities.

Although the number of sensitive taxa remained elevated, the insects that have developed specialized feeding methods (Predators and Shredders) decreased in a downstream direction. Similarly, proportions of aquatic organisms that are tolerant to stress *(i.e.,* Chironomidae and Non-Insect Taxa) were higher in the Urban zone compared to the Canyon and Rural zones. These changes in macroinvertebrate community structure were likely caused by increases in anthropogenic stress that come with urbanization.

The high grade (A) for the trout metric at Lee Martinez Park, is confirmation of quality habitat, at least locally (Figure 5.9). Multiple age classes, high recruitment level, and high numbers of adult fish indicate a well-supported and naturally-sustaining trout population. Population estimates suggesting 625 quality-size fish per mile and biomass that exceeds Gold Medal standards indicate a quality recreational fishery. These promising data, however, only represent 2015 and data from other years were not as high.

While good for trout, the river's condition in this zone is not good for native fish, most of which have recently been extirpated from the downstream portion of the zone. In the upstream portion of the zone, the available historic fish sampling data suggest that native warm water fish species richness was naturally limited, presumably because of the colder water. Native fish populations rebound some in the downstream reaches of the zone.

As found throughout the SOPR study area, aquatic habitat connectivity is highly fragmented and detrimental to fishery support. Several large diversion dams pose barriers that prevent native fish from migrating to the Urban zone from the plains, therefore, when populations do crash opportunities for recolonization from downstream are limited. Unlike fish, aquatic insects are less sensitive to in-channel barriers and grades fall within the recommended range. An equally concerning factor affecting native fish in the Urban zone is poor floodplain connectivity. Many of these small bodied native fish species require access to the floodplain as refuge from high flow events, and several species require access to the floodplain for reproduction.

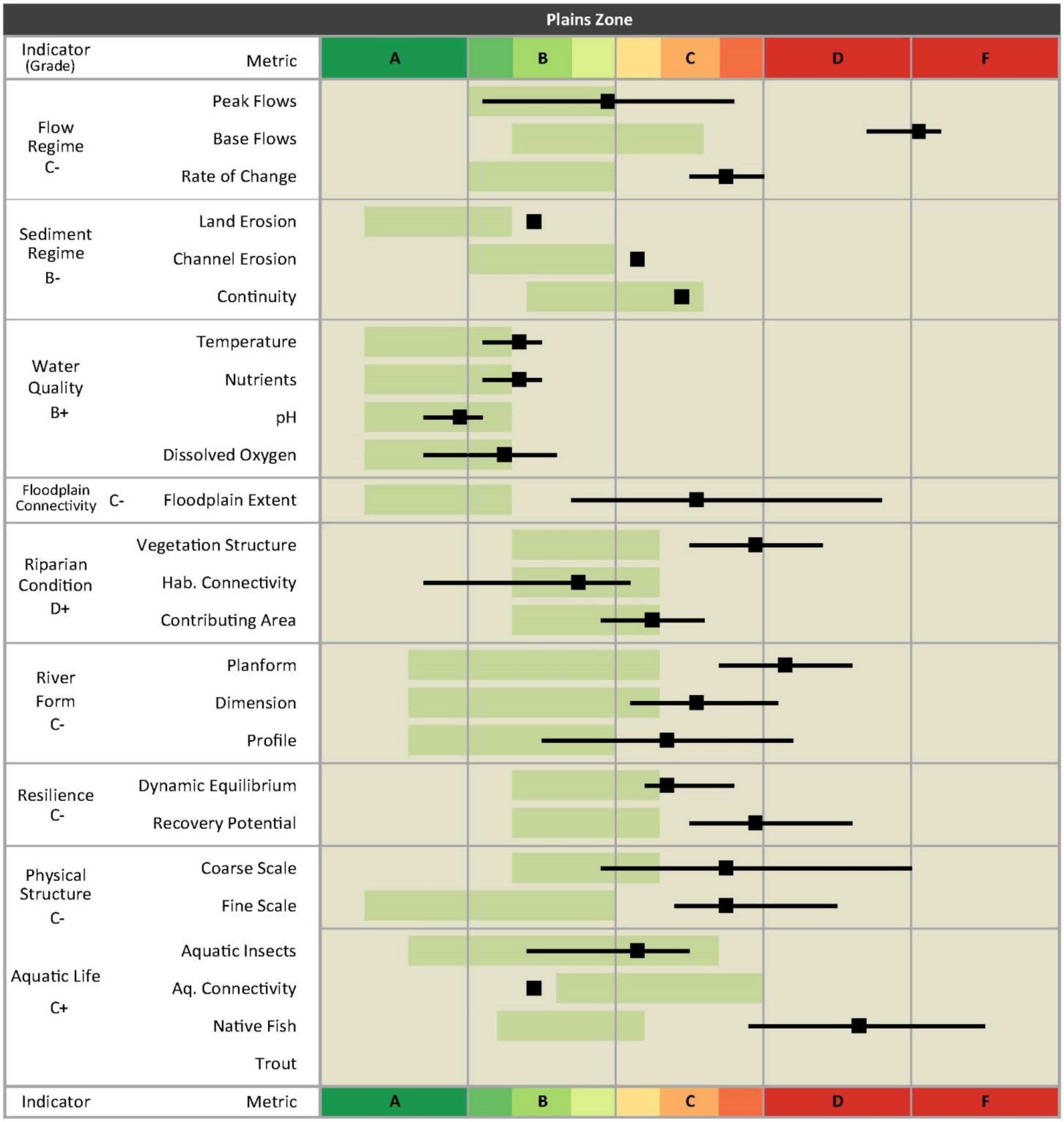
Figure 5.9: While the healthy brown trout populations in the Urban zone indicate suitable habitat conditions for cold water species, their influence as predators on the declining populations of native fish is not well understood (photograph courtesy of Colorado Parks and Wildlife).

5.5 Plains zone

Differentiation between the Plains zone and the Urban zone is largely based on land-use patterns and development rather than inherent differences in ecosystem properties. Historically the river would have continued to braid, with waters becoming warmer and bed material finer. A stretch of multi-thread channel exists in the broad floodplain preserved at Colorado State University's ELC south of Prospect Road, but most of the river has been simplified (Figure 5.10). Diversions continue to impair river health (except for fish movement due to recent installation of fish passage), as do berms, channelization, bank armoring, and impervious surface runoff upstream of this zone. Basically, all the land-use modifications that come primarily with mineral resource extraction in the floodplain influence this zone (Table 5.5).

Figure 5.10: In the Plains zone the river has some opportunity for good connectivity with the floodplain which results in higher function through the system and allows for periodic flooding of the riparian zone (left). However, through much of the Plains zone the channel is continues to be highly confined by ponds and berms on either side drastically altering its function (right).

Table 5.5: Metric grades in relation to recommended ranges for the Plains zone. Recommended ranges (green bars) represent expert opinion for reasonable and practical potential metric grades given existing land and water- use constraints. Points (square black boxes) present the average grade for the given metric for this zone. The black lines show the range of results across the reaches within this zone.



Flow and sediment

As in the Urban zone, most metrics in the Plains zone have grades below the recommended ranges. Flow regime scores on the Plains zone were similar to those in Urban zone, but the peak flow metric received a B- compared to C. The better grade in the Plains zone does not reflect an actual increase in peak flow hydrology, but rather a reduction in bed material size that potentially increases the ability of peak flows to mobilize stream bed material and flush it through the system. Therefore, even though observed magnitude and frequency of peak flows have been lessened, they are still considered sufficient for basic streambed maintenance functions in this zone. On the other hand, functions affected by diminished peak flow hydrology, such as floodplain activation, recharge, and riparian support are significantly reduced. Base flow conditions are at their worst on the Plains zone, where frequent dry-ups and critically low flows severely limit aquatic life. Grades for all these metrics are lower than the recommended ranges.

The sediment regime scored a C+ in the Plains zone. The grade is driven by the channel erosion metric, which fell below the recommended range at a C+. Despite the river flowing through large areas of land managed as conserved open lands, bank armoring and channelization continue to impact the sediment regime. Like the Rural zone, the altered sediment supply is also creating accelerated bank erosion in areas without riprap due to the river's increased capacity to transport sediment.

Because much of the area in this zone is conserved land, the opportunity may exist to better allow the river to adjust but cumulative impacts of multiple diversions upstream severely impact the river's flow regime directly influencing the sediment dynamics. Opportunities for improving sediment metrics in the Urban zone are limited due to encroachment of development and the need to protect infrastructure near the river. The City of Fort Collins Utilities' Stormwater Management Program enforces and implements several management practices aimed at reducing stormwater runoff impacts to the river. Erosion control practices during construction help to reduce undesired sediment from entering the river.

Water quality

Water quality is diminished compared with upstream zones but remains relatively high through the Plains zone. In this zone, grades for nutrients and temperature are lower than the recommended ranges, while dissolved oxygen scores hover at the lower limit of the recommended range. The relatively lower grades reflect the combined influences of urban stormwater runoff, treated wastewater effluent, and lower river flows.

River channel *(river form, resilience and physical structure indicators)*

River form is highly altered from the historic condition in the Plains zone. Approximately 70-80% of the river length is channelized or bound by berms, and more than half of it is armored. Floodplain extent is severely limited as a result. Like the zones upstream, the dependence on artificial measures to maintain river form indicates poor resilience and limited recovery potential. The channelized river form and lack of woody material are responsible for impaired physical structure and lack of habitat diversity on most of the zone, where most reaches exhibit homogenous run habitat and few riffles, pools, side channels, or backwater features. Channel structures such as bridges, dams, and weirs are fewer and spread farther apart compared to the Rural and Urban zones, but they are still the most important stressors to river form, structure and resilience on the sub-reaches where they do occur.

Riparian corridor *(floodplain connectivity and riparian condition indicators)*

The Plains zone holds some excellent patches of dynamic, resilient riparian habitat, such as that in the Riverbend Ponds Natural Area and at the ELC. Yet these are few and far between because ponds and berms (along with the Boxelder Treatment Plant), narrowly encroaching on the channel seriously impair riparian vegetation condition throughout much of this zone. Vegetation structure and complexity is well below the recommended range, at the low end of the C range. This indicates that vegetation has only a tenuous hold on healthy functioning.

The ELC has some of the highest-quality—or at least most extensive— riparian habitat in the SOPR study area (Figure 5.11). In this reach, the split channel creates a wide riparian zone. Although variously wooded and an outstanding resource, much of the habitat in the interior is essentially "high and dry" and disconnected from the river; therefore, its ability to support river health is diminished.

Figure 5.11: In the Plains zone, a stretch of multi-thread channel exists in the broad floodplain preserved at Colorado State University's ELC south of Prospect Road (above). The river in the ELC is a contrast to the simplified river form that exists in much of this zone.

Habitat connectivity was generally good and within the recommended range in the Plains zone. Reductions in connectivity were usually caused by the narrowing of native riparian vegetation – most commonly as the result of gravel mining. Prospect Road also crosses the river and riparian habitat and creates a break, but fortunately the bridge underpass provides a protected corridor for organism movement and passage for water and materials.

The contributing area of reaches in the Plains zone were on the average just within the recommended range for maintaining river health. Open, vegetated habitats cover most of the areas that have not been mined and converted to water storage. Because most of the ponds are isolated from the river, they do not contribute positively to river health, but they also do not cause major ongoing negative effects on the river and the remaining riparian habitats.

Aquatic life

Aquatic insect grades range from B to C, and all reaches scored within the recommended ranges. Native fish grades range from C- to F in the Plains zone. Most native fish species are either extirpated from the zone or at risk. Trout were not graded in the Plains zone because this warmer segment of river is not natural habitat for these cold water-fishes. Aquatic habitat connectivity is greatly improved in this zone, compared to the Rural and Urban zones,largely due to the installation of fish passage at one of the major diversion dams. Because aquatic habitat connectivity is greatly improved on the Plains zone compared to reaches upstream, the average grade exceeds the recommended range. Nevertheless, barriers downstream of the study area limit upstream migration of native fish, so when populations do crash locally, it is difficult or impossible for them to recover naturally (through immigration from downstream waters).

Many factors are negatively affecting native fish species richness in the Plains zone and contributing to their decline, particularly poor base flow conditions and seasonal dry-up of certain reaches. As in the Urban zone, poor floodplain connectivity diminishes habitat quality for native fish that require access to the floodplain to carry out basic life history functions. Numbers of brown trout have also recently increased above historic levels in upstream portions of this zone suggesting marginally cold thermal conditions for warm water native species. Finally, the proportion of other warm water non-native species has increased in this zone. Many of these species may indirectly compete with native species for resources, while others such as largemouth bass suppress native populations directly through predation.

While the results from the aquatic insect evaluation for the Plains zone produced an overall B- grade, many of the sub-metrics detected a general increase in stress in a downstream direction. An evaluation of taxa that are sensitive to stressors indicated that there was some decline in the richness of these species; however, the Clinger Taxa sub-metric produced scores that were identical with the rest of the study area. Despite the variable responses among some metrics, a distinct reduction in specialized feeding groups (demonstrated by the Predator and Shredder Taxa sub-metric) was observed, while the abundance of taxa that are usually tolerant to disturbances increased in the most downstream portion of the study area. In general, negative impacts affecting aquatic insect communities appeared to increase in the downstream portions of the Plains zone, yet evidence suggests that aquatic conditions were adequate for maintaining moderately healthy communities of these organisms.

5.6 Potential opportunities for improving river health

The goal of this section is to identify the types of opportunities where the City may be able to most effectively improve river health and resilience by strategically applying its resources. The following section is provided as a high-level description of management possibilities rather than a site-specific set of priority actions.

Flow

Achieving improvements on the river will be challenging since the amount and timing of the multiple diversions on the Poudre River are governed by water rights that are administered by the State according to strict legal procedure. Water rights administration is largely outside the sphere of influence of the City. The existing (and future) diversions on the Poudre River support local food production and the water needs of our homes, businesses and institutions. Concepts for improvements to the river will need to consider these historic rights and may require some type of compensation if historic diversions are not maintained, operations become more costly, or physical structures need to be altered. There may be opportunities for improvements that minimize impacts to these water users (as described below), but doing so will take collaborative efforts with many stakeholders.

From the Canyon zone to the Plains zone refining water management operations to better mimic the natural flow regime would improve river health and grades. In the Canyon zone, a more natural flow regime would especially benefit the rate of change metric. Out of the canyon, water management becomes increasingly complicated due to the multiple diversions for irrigation and municipal water needs, including those by the City of Fort Collins. Known dry up locations could be good focal points for collaborative flow related initiatives aimed at reducing the frequency and severity of complete dry-up events during critical low flow periods. Water exchanges and creative uses of local storage could be effective tools for improving base flow conditions~~.~~

Improving base flow in the Urban and Plains zones would require major changes to water management and diversion operations in order to elevate the current grade ranges of D to F+ to the recommended C (or greater). Achieving this level of improvement is highly aspirational, but even small improvements could make a big difference in the health of the aquatic habitat. Improving the rate of change metric from C- to the recommended minimum B- may be more attainable goal since this could be accomplished by ramping diversions so that river flows change less drastically over short periods of time. For example, local storage releases to diversion points lower on the river could be made in a manner that avoids sudden flow changes and yet maintains the same volume of delivery. Improving peak flows (mention zones if you want) may also prove to be challenging, since these flows are typically diverted throughout the watershed to fill local storage reservoirs and provide local irrigation and municipal water needs.

However, there could potentially be better coordination among local water users and the river administrators to consider short periods during which administration of the river could potentially be implemented in a way that would allow higher peak flows to provide ecological benefits to the river. For example, in particularly high snowpack years when there is consensus that there will be more than enough runoff to meet all the basins water needs, much of the diversions could be curtailed for 1-3 days during the projected highest runoff period to allow for better flushing flows. Again, this type of operation would require close and willing collaboration with the various stakeholders in the basin.

Water Quality

Water quality is quite high in the Canyon zone. The metrics that are most impaired— temperature and dissolved oxygen—could possibly be improved by changing dam and reservoir operations, but it is unclear which changes should be implemented to bring about the desired effects. Detailed study and modelling would be necessary to make prescriptions for actions to improve water quality in the Canyon zone, because unguided action could exacerbate problems.

Downstream of the canyon, opportunities for improving water temperature seem technically feasible but again it would probably involve changing water operations. Water operation changes are notoriously challenging and usually expensive, therefore, improvements in temperature are unlikely in the near term.

There are irrigated agricultural lands influencing the SOPR study area, specifically in the North Fork watershed, within the Rural zone, and near the Dry Creek and Box Elder tributaries that feed the Poudre River. Nutrient metric grades indicate impacts from irrigated agriculture are currently a low stressor to the Poudre River. If water quality monitoring efforts indicate pollution inputs from irrigated lands, then best management practices could be recommended to improve agricultural runoff and decrease nutrient loading. The City has no control over privately owned agricultural land so stakeholder partnerships and participation would be necessary to mitigate impacts from agriculture.

River channel *(river form, resilience and physical structure indicators)*

The physical setting is described through the four indicators: river form, structure, and resilience. In the Canyon zone*,* physical constraints limit the range of improvements that could occur and because a large proportion of the physical impairment in the zone is tied to the highway and dams, there is little opportunity for improving these aspects of river health.

Below the canyon, there are a number of technically feasible ways that the physical characteristics of the river could be improved. Creating bridge designs that incorporate appropriate bridge spans and adding floodplain culverts could reduce river health and resilience impairments. Increasing floodplain connectivity near bridges in conjunction with floodplain culverts could help ease flow constriction through bridges, improve sediment transport, and provide drainage if the bridge were to become clogged during a large flood event. These actions would greatly increase resiliency in the face of large flood events. Reclaiming abandoned roads and removing non-essential bridges, constrictions, and relict in-channel structures may be feasible in the areas where they exist and these improvements would be a benefit in any of the zones.

Even in the most urban areas, potential opportunities exist for improving the river's physical form and function. In general, offsetting berms (when possible to beyond the 100m riparian zone), setting multi-use paths further back (when due for replacement), removing or offsetting bank armor (unless it is necessary to protect infrastructure), restoring natural stream form in undeveloped open areas could greatly improve river health and resilience. These actions would improve floodplain connectivity, river form, resilience, and structure by decreasing entrenchment and allowing the river to adjust planform. This would allow the river's energy to decrease during floods by spreading water over the floodplain, slowing velocities, and increasing sinuosity. These mechanisms of dealing with floods are less expensive and more resilient, over the long-term than trying to make channels strong enough to resist the high energies generated by flood flows. It also allows the river to be dynamic, which is important for maintaining structural complexity, habitat diversity, and healthy riparian vegetation.

Some berms may be able to be removed outright. For instance, many of the naturalized open spaces and Fort Collins Natural Areas are channelized or have berms close to the channel where their close proximity may not be critical to health or safety. Rehabilitation or removal of these features would open floodplain access, restore river form, and improve riparian condition. Furthermore, these undeveloped areas could be utilized as areas where floodwaters could spread, drop sediment, and slow down to help protect entities downstream. The City of Fort Collins Natural Areas Department recently completed the successful removal of the Josh Ames diversion and associated riparian restoration projects at Sterling and McMurry Natural Areas (just upstream and downstream of Shields Street respectively). Similar beneficial opportunities may exist elsewhere, but the main challenge is that these types of projects are expensive and difficult to implement given the various engineering and regulatory issues they present.

When riprap is necessary, the way it is installed can lessen its negative effects. For instance, offsetting and burying riprap right at the protected structure may provide increased resiliency during large flood events by allowing the river to erode banks and dissipate energy. Furthermore, during large flood events rivers will move and possibly even avulse into a new channel. By allowing the river as much room as possible to move during large flood events, management works with natural processes instead of trying to halt them. Ignoring natural processes may increase risk of harm and costly impacts during high floods in the very areas we are trying to protect.

Riparian corridor *(floodplain connectivity and riparian condition indicators)*

In the Canyon zone, riparian condition is generally good, and since the small-degree of impairment here is directly related to encroachment by the highway, there is little opportunity for improvement other than maintaining best management practices, addressing noxious weed issues, collecting litter, etc. Most of the practices must be carried out by individuals and entities other than the City.

Downstream of the canyon, areas with rural-land use or light agriculture have some capacity for maintaining at least patches or strips of native riparian vegetation alongside existing uses. In fact, some of the forested patches in light agricultural areas scored among the highest in the entire study area, especially near the canyon mouth. These forests have fewer problematic woody species and better canopy structure than most of the habitats downstream. Stewardship and riparian restoration may, therefore, be potential options for improving riparian condition if landowners are interested. The average riparian condition grade on areas mapped as rural, pasture, or light agricultural land use is D+, but the range extends to C+. This range suggests that there could be potential for improvement at some lower condition sites. The City does not own or manage lands in the Rural zone, so improvements to riparian habitats in that zone would be voluntary, landowner-led efforts; although the City could potentially help support improvements through a variety of means.

In the Urban and Rural zones, improving the character of foundational processes such as opportunities for flooding, scour, and deposition would drive a cascade of positive influences throughout affected riparian areas.

Other potential riparian improvements include improving the recruitment of large woody material and leaving woody material in the river to the greatest extent possible. In areas where the surrounding and downstream land is relatively undeveloped, increasing floodplain extent and tolerance for some degree of channel migration in naturally forested areas is also a mechanism for improving recruitment of woody material recruitment. These refinements in management would increase structural diversity and aquatic habitat heterogeneity. But woody material can also cause damage to bridges, dams, berms, and other structures, so there will always be some need to manage how and where wood is allowed to contribute to river dynamics. Maintenance strategies that employ selective, rather than complete, removal of wood could provide river health benefits, while still protecting infrastructure.

Aquatic life

One of the biggest impacts to aquatic life in the study area is habitat fragmentation and migration barriers caused by the diversion dams. Construction of fish passageways or other passage mechanisms would lessen the impact of dams on fish migration, and such measures would elevate the aquatic habitat connectivity scores (Figure 5.12). Facilitating fish passage at diversion dams would also allow fish to access the mosaic of habitats vital to different life history attributes, and would allow recolonization following localize population crashes. Such measures would seemingly lead to increases in fish populations and certainly fishery health.

Figure 5.12: Recently installed fish passageway at the Fossil Creek Inlet Ditch just downstream of Prospect Avenue.

Across aquatic life metrics and river reaches aquatic habitat could be enhanced by improving flow metrics as discussed above. Low flows and dry ups during summer and winter months are known limiting factors to aquatic life health. Improvement to flow characteristics would mitigate thermal stresses, support desired dissolved oxygen levels, increase the amount of aquatic habitat, flush interstitial spaces for aquatic insects, and reduce the habitat fragmentation caused by dry ups.

Projects increasing habitat complexity, especially those which result in increased pool habitat, would definitely bring benefits to aquatic life. Use of large wood material and other scour providing materials could lead to increases in habitat scores and greater fish numbers and health. Promoting habitat at the tributary nodes of storm water return, irrigation return, and other small tributaries for production of some native fish species paired with active translocation of species would further improve the aquatic species populations. Continued stocking and evaluation of rainbow trout recruitment and survival in the face of whirling disease and high brown trout densities is an objective of Colorado Parks and Wildlife for the Poudre and similar Front Range rivers.

Aquatic insects have evolved and adapted to the healthy aquatic conditions that historically persisted in Colorado streams for eons. Many of the human activities in the Poudre River watershed alter water quality or habitat resulting in a shift in aquatic insect community structure or function. Accurate and consistent sampling and monitoring of aquatic insects is important for the documentation and evaluation of stress-related shifts in aquatic life over time. Long-term biomonitoring studies also provide valuable information that can be used to identify trends and help distinguish between natural variation and impacts from anthropogenic stressors which could then potentially be addressed through management actions.

6 Looking forward

A primary goal of the SOPR is to foster management approaches that consider river health and function in a more comprehensive fashion. The SOPR takes a holistic and science-based approach, and provides a platform for evaluating operational, management, and policy options for preserving or enhancing river health. It is a tool for weighing outcomes and evaluating tradeoffs in the currency of river health. This first SOPR assessment also serves as a benchmark for monitoring river health changes into the future.

The SOPR is intended to serve to enhance the collective understanding on the potential impact of projects or decisions and to provide a means to effectively evaluate and prioritize opportunities, measure progress, and communicate results (Figure 6.1).

Figure 6.1: Colorado Water Institute staff Reagan Waskom and MaryLou Smith lead a community dialog at the annual Poudre River forum.

6.1 The future of the State of the Poudre project

Continuing this project through repeat assessments on a periodic basis (3-5 years) allows it to serve as a tool for following a “plan, do, check” management approach. Using this strategy, the results of SOPR assessments can first be considered by City staff and collaborators. Next, reach and metric specific goals, scores and stressors can be linked to create management priorities (Figure 6.2). Then the subsequent version of the State of the Poudre can help us reflect, or “check” on the progress we are making towards our goals.

Figure 6.2: Diagram illustrating the process whereby the SOPR may be applied to inform management priorities and track river health trends over time.

The metrics included in this study are each distinct and therefore need to be measured on specific time scales. To support subsequent iterations of this project data for some metrics should be collected annually, or perhaps data gaps filled. Other metrics change more slowly and need to be measured on less frequent intervals. These metrics may not be revisited until the next full assessment. The following section presents a list of recommendations developed by this project team of potential methodological improvements and enhancements that could be made in the future.

6.2 Potential improvements to the SOPR methodology and data

- While maintaining this existing approach for evaluating peak flows, a potential addition for understanding this metric would be to evaluate new locations for scour analysis thresholds, collect evidence of “flushing” using tracer rocks, and/or use point flow model to understand local conditions at discrete (diversion) points. Also a quantitative approach could be developed for evaluating flows in the Canyon zone.
- Work with collaborating organizations to catalyze a landscape-scale fish movement study to improve understandings of the relationship between fishery health, movement and the suite of stressors. This study would not become a regular part of the SOPR, rather it would provide

important insight and additional evidence to supporting various scores associated with fish and fish habitat.

- Continue annual insect data collection, generally during both spring and fall (including new data points initiated in 2016 to inform this project). Review 2016 fish data including the sampling location in from the Rural zone. Conduct field assessment of valued riparian sites not assessed through a 2016 on-site evaluation for this baseline assessment.

Wrap Up

For the first time, the City of Fort Collins has a comprehensive baseline of river condition. From here forward, this tool will help the City and the region measure efforts to sustain, maintain, and improve river health. Ultimately, the SOPR is an act of faith in the future and an example of the City's commitment to the plan-do-check-act cycle (Figure 6.3).

Ultimately, a well-stewarded river contributes to the long-term success of our community, which has for over a century depended on the Poudre. As challenges to water security and ecological health mount over the next century – it will become ever more important for decision makers to have powerful tools like the SOPR at their disposal, to inform critical decisions. With good tools, and some hard work, our community will be in a better position to sustain the cherished values of the beloved Cache la Poudre.

Figure 6.3: City of Fort Collins Watershed Education Coordinator Alicia Sprague teaches school children about the relationship between water quality and sensitive aquatic insects.

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