FINAL

Yampa River Scorecard Project
Middle Yampa Segment Results and Scoring

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YAMPA RIVER
SCORECARD
PROJECT

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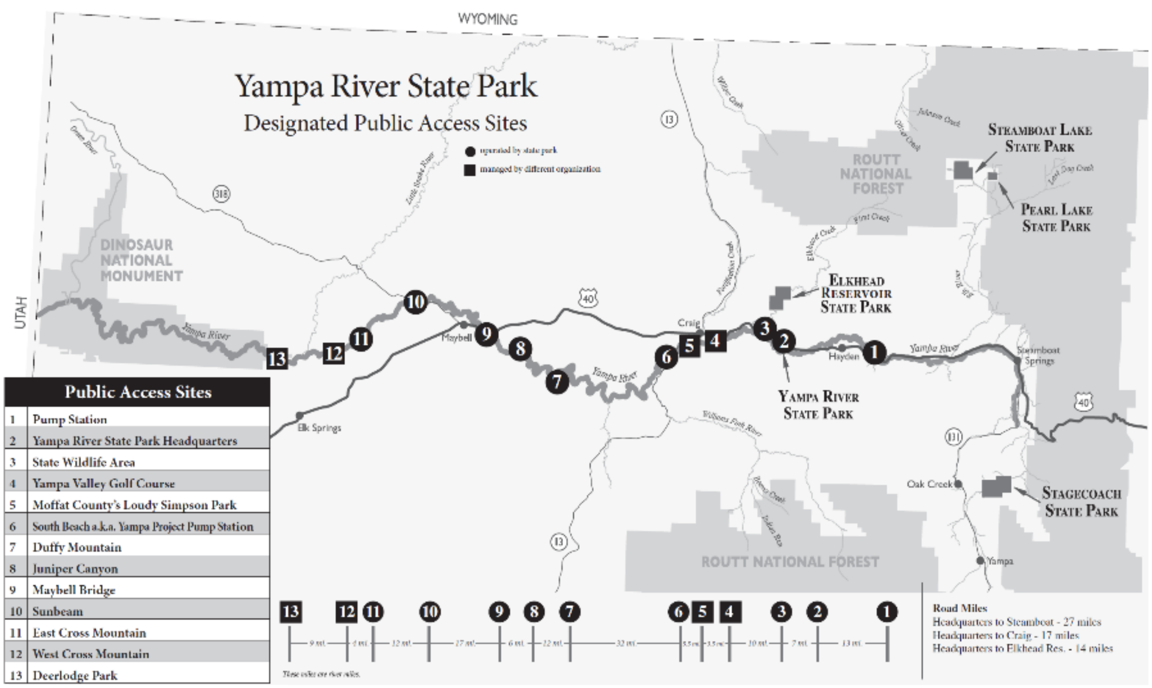
1.0 INTRODUCTION

Friends of the Yampa is leading a community-based process to implement a long-term river health monitoring and evaluation program for the Yampa Basin that rates the overall condition of different segments of the Yampa River and articulates results through a *Yampa River Scorecard*. The first iteration of the Yampa River Scorecard Project (YRSP) is focused on the Middle Yampa River segment of the Yampa main stem, a 39-mile segment from the Hayden pump station to South Beach. Figure 1-1 shows public access points along the Yampa River. The Scorecard focal segment corresponds to points #1 through #6 on this map. The Xcel Pump Station (sometimes referred to as Pumphouse) is a Colorado Parks and Wildlife (CPW) public river access site approximately 5 miles east of Hayden, just upstream of The Nature Conservancy's Carpenter Ranch in Routt County. The segment flows through Morgan Bottom, the Town of Hayden, Yampa River State Park Headquarters, the Yampa River State Wildlife Area (also known as Dorsey), the City of Craig, the Yampa Valley Golf Course (also known as Pebble Beach), and Loudy Simpson Park in Moffat County. The downstream boundary of the segment is the South Beach (also known as the Yampa Project pump station) public river access site, located approximately 3 miles south of Craig upstream of Little Yampa Canyon.

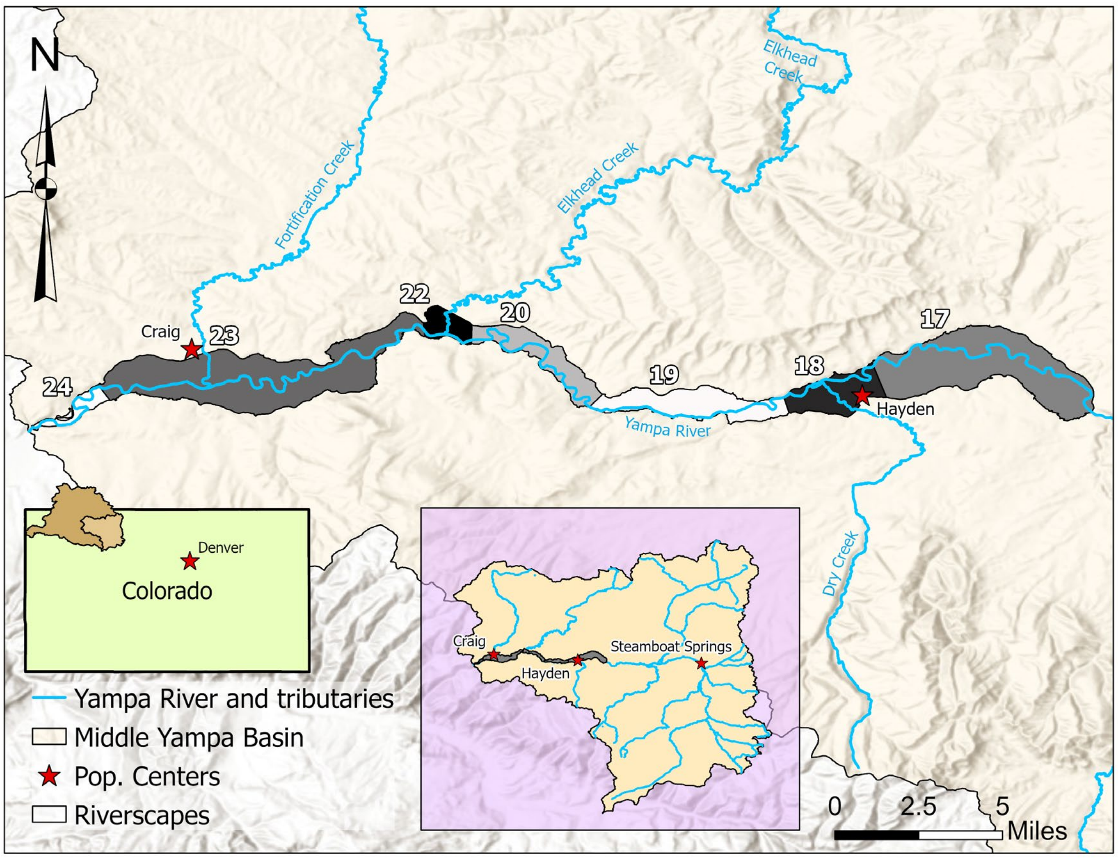
Figure 1-1. Yampa River Public Access Sites



Seven riverscapes identified in the Yampa Integrated Water Management Plan (IWMP) remote assessment are contained within this segment (Figure 1-2). A score for each indicator will be developed for each riverscape, and then averaged for an overall riverscape score (refer to Section 11 for more information). A weighted average across the seven riverscapes will then be calculated to generate an overall ecological health and function score for the Middle Yampa River Segment.

More information about the Yampa River Scorecard Project goals; background on determination of the focal segment for the first iteration of the Scorecard; information related to the three stakeholder-identified attribute areas that are be evaluated as part of the Scorecard effort (river uses and management, people and community benefits, and ecological health and function); and details specific to the categories, indicators, monitoring methods, and scoring criteria used to assess the ecological health and function attribute area are provided in the Yampa River Scorecard Project Indicators and Methods Report (FOTY/Alba Watershed Consulting 2021). To encourage community-wide engagement and contribution to tracking river health, the monitoring and evaluation process is communicated using concise, clear, and visually appealing methods; visit https://yampascorecard.org/ for the YRSP public interface.

Figure 1-2. Middle Yampa River Segment Riverscapes



This document details the results and rationale behind scoring of the ecological health and function attribute area for the Middle Yampa River scorecard focal segment. The YRSP Technical Committee agreed on a set of categories to evaluate river health and function, largely based on the Functional Assessment of Colorado Streams (FACStream, Beardsley et al. 2015), a reach-scale assessment tool developed for the US EPA and State of Colorado that rates stream health according to the degree of impairment of several ecological variables, and the Colorado Stream Health Assessment Framework (COSHAF), a stream health assessment framework based on the FACStream variables used in many stream management plans (SMP) across Colorado, including an SMP completed by the City of Steamboat Springs covering a 12-mile section of the Yampa River through the City (City of Steamboat Springs 2018). COSHAF uses 11 variables to: evaluate the key factors that determine the health and resilience of a stream reach, ensure that all relevant aspects of stream health are considered, and serve as a guide for determining which monitoring parameters are most relevant. Other river-related report card efforts, particularly the Eco Health Report Cards undertaken by the University of Maryland Center for Environmental Science and its partners, were consulted as well. Based on these existing scorecards and ongoing input from the Technical Committee, the following categories were identified for evaluation:

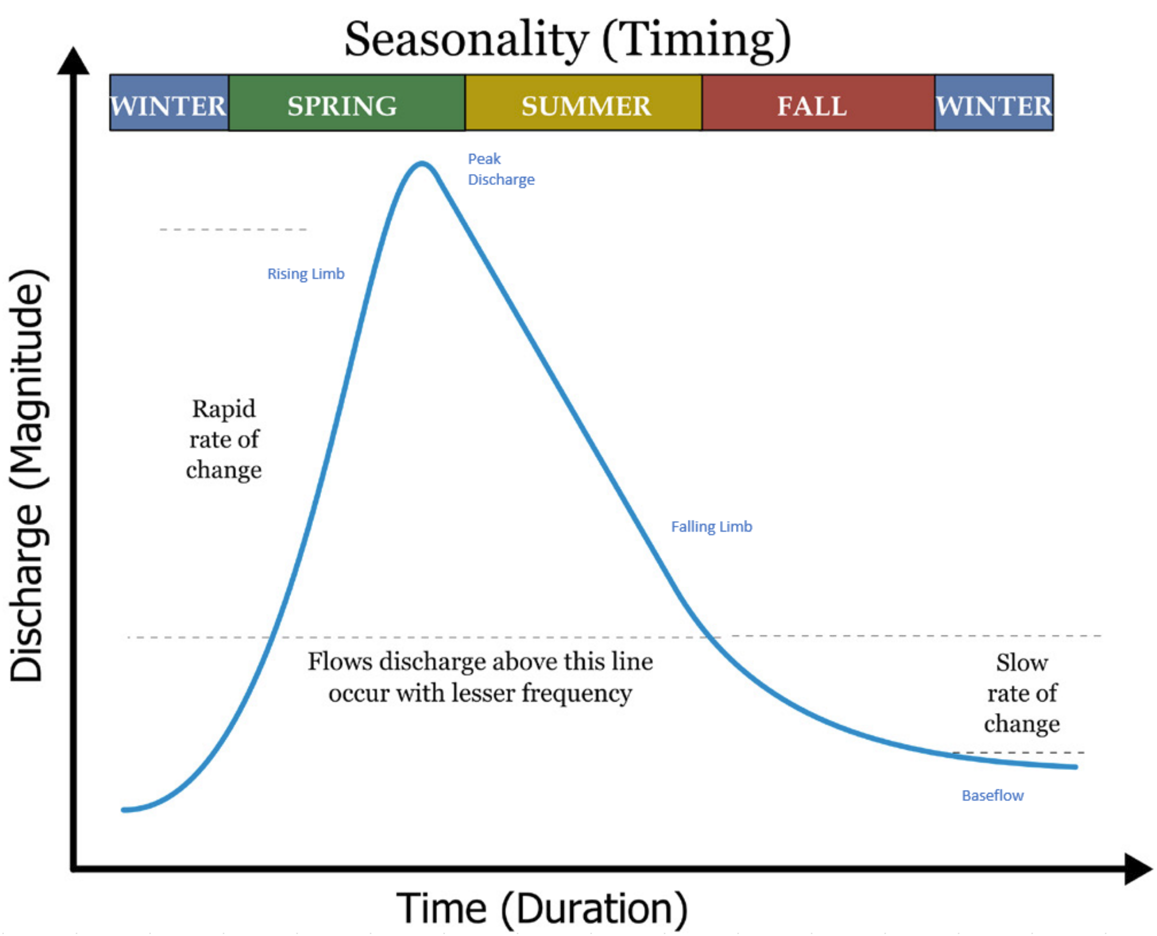
- Flow Regime (amount and timing of water supply);
- Sediment Regime (amount, timing, and type of sediment supply);
- Water Quality (physicochemical properties of water);
- Habitat Connectivity (aquatic and terrestrial habitat connectivity);
- Riverscape Connectivity (frequency, extent, and duration of riverscape saturation or inundation);
- Riparian Condition (riparian habitat condition, including vegetation structure, diversity, and invasive species);
- River Form (channel morphology including planform, dimension, and profile);
- Structural Complexity (physical habitat including water depth, velocity, structural components, and substrate); and
- Biotic Community (community and trophic structure of the organisms in the reach).

The remainder of this document describes the suite of categories and indicators that, when evaluated, provide a comprehensive understanding of river health and function across the Middle Yampa River segment. Each sub-section discusses one of the nine categories listed above, with further subdivisions by indicator. The discussion of each indicator contains a description of the indicator, the data sources and methods used to evaluate the indicator, the scoring criteria that are applied, the results and rationale for scoring, and associated scores. Existing data are used to the extent possible, supplemented by additional data analysis and field data collection where specified.

2.0 FLOW REGIME

Flow regime is defined as the characteristic pattern by which water is supplied to a river segment from its contributing watershed. It is often represented by a hydrograph, and is dictated by precipitation, inter- and intra-annual weather patterns, watershed characteristics, and human influences. Flow regime is a primary determinant of a river's structure and function. In particular, the magnitude, duration, frequency, and timing of river flow interact with the landscape to determine the functions that the river performs. The Yampa River Scorecard evaluates two indicators within the flow regime category: the overall **hydrograph** and the annual **snowpack**. Figure 2-1 provides a schematic diagram of an annual hydrograph, illustrating important concepts such as peak discharge, base flow, and rising and falling limbs. The final flow regime score is calculated as 90% hydrograph indicator score and 10% snowpack indicator score. The Technical Committee decided on this uneven split to avoid double counting and consider the fact that snowpack is a driver of flow regime and exerts a major influence on the elements of the hydrograph indicator.

Figure 2-1. Hydrograph Schematic Diagram



2.1 HYDROGRAPH INDICATOR

The hydrograph indicator considers the following components of the Yampa River's flow regime:

- Magnitude, timing, and duration of **peak flows**. Adequate peak flows are essential to river health and function. Snowmelt-driven peak flows during spring runoff are important for numerous watershed services, such as fishery support, riparian habitat quality, sediment flushing, water quality maintenance, recreation, aesthetics, and groundwater connection and recharge.

- Magnitude, timing, and duration of **base flows**. Base flows are the low flows that occur after snowpack melt, during dry season, usually from late summer to early spring. They provide critical support of aquatic habitat and riparian connectivity when the stream needs it most after peak flows have receded. Sources of base flows are rainfall events and slowly percolating groundwater, and they can be augmented by reservoir releases and irrigation return flows in managed systems.

Please note that total annual volume (the amount of water delivered to the riverscape from its contributing watershed) and hydrograph form (the shape of the hydrograph, including timing and duration of rising and falling limbs) are also important components of flow regime in the Yampa River basin but are not included in the scoring for this indicator due to lack of available modeled data.

2.1.1 Data Sources and Evaluation Methods

Development of scores for this indicator relies heavily on existing USGS stream gauge data, augmented by local knowledge. As a holistic indicator, this variable uses expert judgement and review and analysis of available data to generate a single score for the hydrograph indicator. The rationale behind that score is heavily influenced by the peak flow and base flow components of the hydrograph discussed in the previous section.

The stream gauges within the Middle Yampa River segment are as follows:

(1) USGS 09244410 YAMPA RIVER BELOW DIVERSION, NEAR HAYDEN, CO – This gauge is just upstream of Carpenter Ranch and no longer operational (1965-1986).

(2) USGS 09244490 YAMPA RIVER ABOVE ELKHEAD CREEK NEAR HAYDEN, CO – This gauge is located just upstream of the confluence with Elkhead Creek (2004-2021).

(3) USGS 09247600 YAMPA RIVER BELOW CRAIG, CO – This is an active gauge located below Craig (1984-2021).

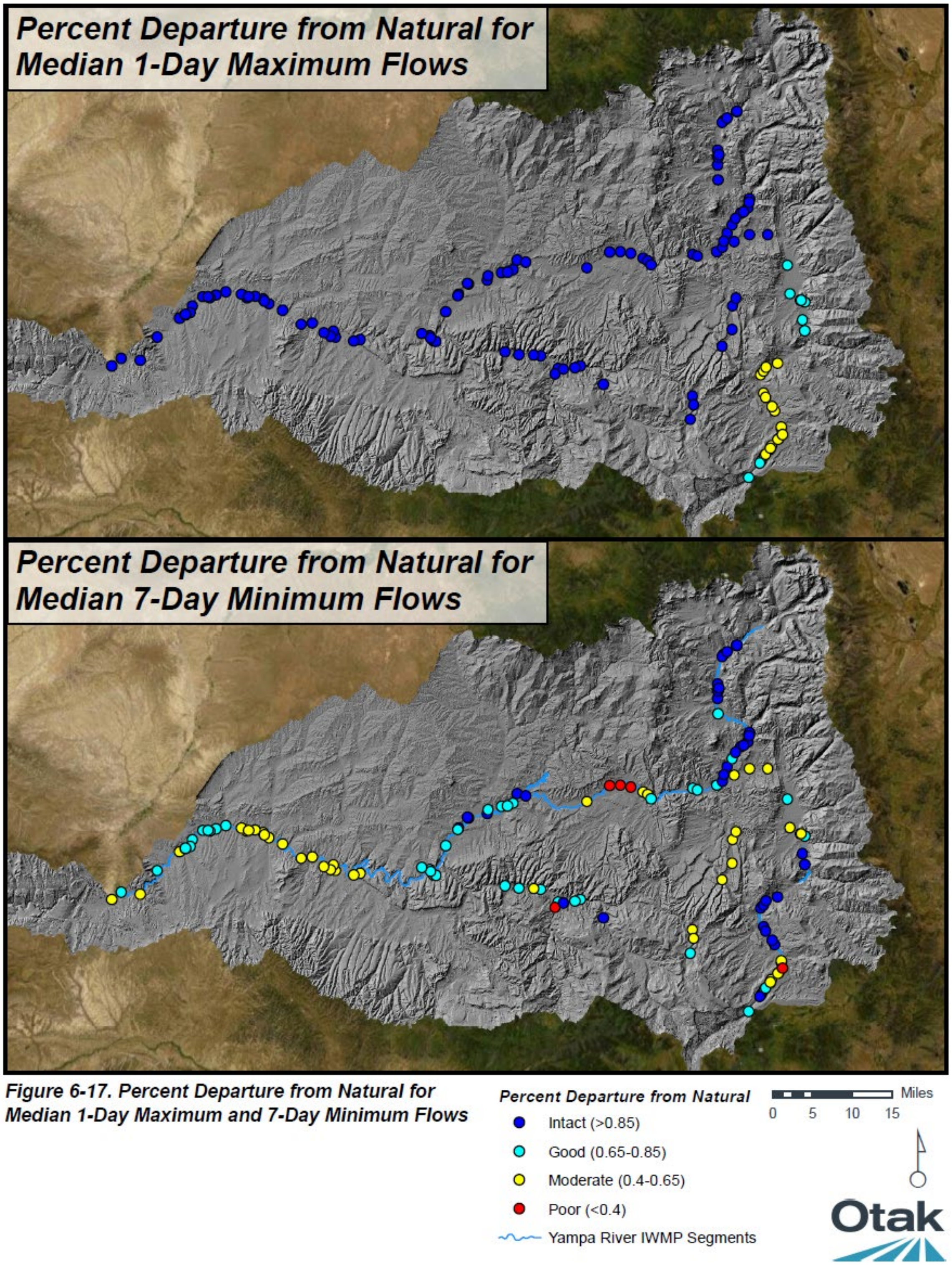
The Wilson Water Group (WWG) conducted hydrology modeling for the Basin Implementation Plan Phase 3 (WWG 2018), where these and other stream gauge nodes within the Yampa Basin were used to explore the potential benefits and impacts of Yampa-White-Green Basin Roundtable projects under different hydrologic scenarios, including natural streamflows, baseline streamflows, and future scenario streamflows. The modeled natural flow regime is derived by removing the influence of human activities from current recorded streamflow to estimate natural, undisturbed flows at locations on the Yampa River. Disturbance activities that can be accounted for include diversions, irrigated agriculture and return flows, storage and releases, and water rights administration. Existing streamflow conditions, referred to as baseline conditions, represent recorded diversions, current consumptive demands, administration, instream flow and recreational in-channel diversions (RICD), existing infrastructure, and reservoir operations, and include modifications based on water-user interviews. While the WWG modeling did not include pre-measurement changes to hydrology or paleohydrology in establishing “natural” streamflows, the authors of this report acknowledge the relative recency of the USGS stream gauge data.

The Yampa IWMP remote assessment’s Data Synthesis Report (Yampa IWMP 2021) applied these data to percent departure of baseline conditions from natural conditions for two metrics: (1) percent departure of high flows and (2) percent departure of low flows. The two metrics were used in the remote assessment to provide a high-level, holistic indication of flow regime alteration within the Yampa basin (Figure 2-2). A more detailed hydrologic analysis of more than 107 metrics is presented in the Yampa River Hydrologic Review and Needs Assessment Report (Lotic 2021). This report and its associated data are used to rate this indicator.

To rate the hydrograph indicator, streamflow data from the three gauges listed above, as well as additional streamflow nodes within the 39-mile Scorecard focal segment that are used in the Lotic (2021) hydrologic analysis, were used to determine the departure of existing flow regime from modeled natural flow conditions, as well as to compare the baseline (existing) hydrograph to the modeled natural hydrograph over the period of record. In particular, daily flow data for modeled baseline (modeled existing) and modeled natural flows for all gauges/nodes covering the years 1974-2013 are compared. Future iterations of the Yampa River Scorecard Project will explore acquiring similar modeled data that extends to more recent years (i.e., beyond 2013).

Additional data sources used to augment this review of historical modeled hydrographs are current local knowledge of dry-up points or significantly reduced flow locations that are not reflected in the existing stream gauge records, as well as a recent USGS publication investigating streamflow and water quality in the upper Yampa River Basin from 1992-2018 (Day 2021). This publication also conducts a streamflow trend analysis on the main stem Yampa River over a much longer time period (since 1910).

Figure 2-2. Yampa IWMP Remote Assessment Flow Regime Percent Departure Plots



2.1.2 Scoring Criteria

The descriptive and semi-quantitative scoring criteria outlined in Table 2-1 are used to rate the hydrograph indicator. Each sub-indicator (e.g., 1-day maximum flow) is given a grade and then sub-indicator scores are compiled to yield an overall score.

Table 2-1. Hydrograph Indicator Scoring Criteria

Grade	Description
A	Baseline hydrograph characteristics resemble the natural hydrograph. Magnitude and duration of annual discharge peaks and base flows closely resemble natural hydrograph. Departure from natural median 1-day maximum and 7-day minimum discharge estimated to be less than 10% and lack of observable temporal downward trends in the gage record exists. Lack of significant trend in mean flow.
B	Hydrograph has a near natural seasonal pattern, but peaks are attenuated, elevated, extended, or shortened, with departure from natural median 1-day maximum flow magnitude estimated to be 10-25%. Seasonal 7-day minimum discharge diminished approximately 10-25% or increased by 10-50% compared to natural flow. One-day maximum and 7-day minimum flows lack statistically significant downward trends over time, though some observable trends may be present. Impacts from artificial flow changes are minimal, if any. Mean flows resemble natural and display a lack of statistically significant downward trend over time.
C	Hydrograph has a natural seasonal pattern, but peaks are attenuated, elevated, extended, or shortened, with departure from natural median 1-day maximum flow magnitude estimated to be 25-50%. Periods of biologically critical low flows occur occasionally, and seasonal 7-day minimum discharge is diminished approximately 25-50% or increased by more than 50% compared to natural flow. One-day maximum and 7-day minimum flows display statistically significant downward trends for a given time period (e.g., April flows) but not at the overall annual scale. Rapid artificial flow changes occur occasionally. Mean flows are statistically significantly different through time for some portion of the flow year.
D	Disrupted seasonal hydrograph patterns and/or departure from natural median 1-day maximum flow magnitude greater than approximately 50%. Periods of biologically critical low flows are frequent, with seasonal 7-day minimum discharge diminished by more than 50%. One-day maximum and 7-day minimum flows display statistically significant downward trends for several given time periods (e.g., spring month flows) but not at the overall annual scale. Rapid artificial flow changes occur frequently.
F	Disrupted seasonal hydrograph patterns and/or departure from natural median 1-day maximum flow magnitude significantly greater than approximately 50%. Frequent and extended periods of biologically critical low flows and/or periods of no flow occur, with seasonal 7-day minimum discharge diminished by more than 50%. One-day maximum and 7-day minimum flows display statistically significant downward trends for a majority of given time periods (e.g., all but winter flows) but and at the overall annual scale. Mean flows are significantly different from the period of record at the annual scale. Artificially uniform hydrograph, or hydrographs in which rapid daily fluctuations, are common.

2.1.3 Results

Hydrograph analysis was largely completed from 2020-21 in conjunction with the Yampa IWMP (Wilson Water Group 2018, Lotic 2021, Yampa IWMP 2021). Additionally, relevant data and analyses also come from a USGS report on streamflow and water quality in the Upper Yampa Basin (Day 2021). Results and findings of previous reports regarding the health of the hydrologic regime on the Yampa have been refined and synthesized to integrate into the Scorecard framework. The methodology behind these analyses conducted as part of the Yampa IWMP is outlined above (Section 2.1.1); a more thorough explanation can be found in the body of the referenced reports. Analysis focuses primarily on peak flows and minimum flows, as these correspond most strongly with natural function: the magnitude of a high flow event controls how much of the floodplain is inundated, and for how long, and is therefore of substantial importance for maintaining riparian vegetation health, distributing sediment through and across the river corridor, building structural complexity, and enabling connectivity between in-channel and floodplain habitat; low flows, meanwhile, help to maintain essential aquatic habitat, riparian vegetation, and a healthy fishery, and also influence water quality and sediment transport. Secondary consideration is given to mean annual flow; total flow volume, though an important component of the natural flow regime, is not considered. The omission of this latter factor is chiefly because the parameters analyzed herein (maximum, minimum, and mean flows, as well as the timing of peak flow) encompass those flows that have the most substantial correlation to natural riverine functions. Additionally, selection of the metrics on which to concentrate this analysis was done to remain consistent in methodology; robust prior modeling and examination of minimum and maximum flows was done at fine temporal and spatial scales, as was analysis of mean discharge data and the timing of peak flows. Similarly extensive modeling and statistical analysis of trends in total flow volume required to be consistent with the robustness of prior analysis of other flow metrics would have been needed to be considered in this analysis.

Percent departure in median annual 1-day maximum flows is a metric that reflects the degree to which the magnitude of high flow events has changed during the period of record (1974-2013). The magnitude of a high flow event controls how much of the floodplain is inundated, and for how long. These events are thus of substantial importance for maintaining riparian vegetation health, distributing sediment through and across the river corridor, building structural complexity, and enabling connectivity between in-channel and floodplain habitat. In all riverscapes in which analysis was possible, the departure of the modeled baseline 1-day maximum flow is minimal. In riverscapes 17 and 19, baseline flows are 8% different than natural; in riverscapes 22-24, the departure is merely 5% (Yampa IWMP 2021, Lotic 2021). No modeling results are reported for riverscapes 18 and 20 due to the lack of modeling nodes (i.e., the points of the river at which flows are simulated) in these riverscapes.

In slight contrast, the magnitude of 1-day maximum flows as measured at USGS gages 09244490 (Yampa River above Elkhead Creek near Hayden, CO, located in riverscape 20) and 09247600 (Yampa River below Craig, CO, located in riverscape 24) displays a downward trend at the annual scale for the years 1992-2018, though the trend is not statistically significant (Day 2021). Additionally, at USGS 09244490, 1-day maximum flows have a similar downward trend at the monthly scale: flow magnitudes have trended downwards over the past 17 years in the late spring and mid-summer months (May and July), as well as in the fall thru mid-winter (September-January), though neither trend is statistically significant (Day 2021). At USGS 09247600, a similarly observable downward trend is seen in the winter months (November-March) and mid-to-late summer (July-September), though only the February trend is significant. At both stations, it is likely that the downward trends are driven by reservoir operations at Stagecoach Reservoir (e.g., storage of winter and spring runoff), land-use (e.g., irrigation trends), and climate-related (e.g., changes in snowpack) alterations that have impacted streamflow basin-wide (Day 2021). Overall, while the majority of the above discussed trends are not statistically significant, the observable downward direction suggests that flows during these months may continue to decline in the future. Given the minimal departures in the modeling data and observable but not statistically significant trends in the gage data, each riverscape scores an A for the peak flow component of the hydrograph indicator (Table 2-2).

Percent departure in median annual 7-day minimum flow is a metric that reflects the degree to which low flows have been altered from natural conditions. Modeled departures of 7-day minimum flows from natural conditions are substantial for riverscapes in the vicinity of Hayden – differences are 68% and 57% in riverscapes 17 and 19, respectively. Below Hayden, alteration is notably more minimal; riverscapes 22, 23, and 24 have departures of 14%, 18%, and 14%, respectively (Yampa IWMP 2021, Lotic 2021). Though these differences between baseline (current) flow and natural flow are significant, they are of relatively low magnitude (Lotic 2021). As above, modeling results were not reported for riverscapes 18 and 20 due to the lack of modeling nodes located in these reaches.

In terms of recorded stream gage data, at USGS 09244490, 7-day minimum flows as measured from 1992-2018 show an observable downward trend at the annual scale and at the monthly scale for all months save April, though the trend is only significant for January (a lack of significance that may be attributable to the relatively short period of consideration) (Day 2021). At USGS 09247600, the downward trend is mostly evident in the mid-to-late winter months (January-March) and the summer (June-August), though the trend is only significant for March. Notably, there is an observable positive trend at the annual scale for this gage, though again the trend is not statistically significant. Again, while trends are not statistically significant, the observable downward direction in many months suggests that flows during these months may continue to decline in the future (Day 2021). Riverscape scores for the baseflow component of the hydrograph indicator are provided in Table 2-2.

Trends in modeled mean flows were not analyzed for the Yampa IWMP (Lotic 2021, WWG 2018) but were examined for the historical gage data by the USGS 2021 report (Day 2021) and by Lotic (2021) (though, in the latter, only at USGS 09247600). Findings of the former report are as follows: similar in pattern to those shown by the 1-day maximum flows, an observable downward trend is seen for both gages in the summer months (June, July, and August) at both gaging stations; notably, this downward trend continues at USGS 09264490 through the fall and into the winter, extending into January. As above, these trends are observable rather than statistically significant. A significant negative trend in mean flow does occur for USGS 09267600 in the month of February. There is a lack of trend seen in the data for both stations during the late winter and spring months (February-May). In terms of overall mean annual flow, both stations display an observable (but not significant) downward trend. Because of the more substantial correlation of maximum and minimum flows with natural functions (as presented above), mean flows were given relatively lesser weight in the scoring analysis, but were considered. No significant trends in mean flows were found by Lotic (2021) for USGS 9247600.

Regarding trends at longer timescales, data from outside the focal segment provide relevant and illustrative perspective. Examination of data from 1910-2018 at USGS stream gage 09239500 (Yampa River at Steamboat Springs, CO) reveals downward trends in mean and maximum streamflow at both the annual scale and for the spring and summer months (Day 2021). Significant downward trends in the magnitude of daily mean streamflow for the month of April and a lightly significant (p value = 0.06) shift in the date of peak flow to earlier in the year were also found. These trends, of earlier occurring peaks and declines in annual streamflow, are similar to those observed across the Colorado River Basin and reflect changes to temperature (warming) that have decreased winter snowpack and shifted snowmelt to earlier in the spring. Riverscape scores for the overall hydrograph indicator are shown in Table 2-2.

Table 2-2. Hydrograph Indicator Scores by Riverscape

Riverscape	Peak Flow Score	Base Flow Score	Mean Flow Score	Shifting Peak* Score	Hydrograph Score
Riverscape 17	A	D	B	C	C
Riverscape 18	A	C	B		B-
Riverscape 19	A	D	B		C
Riverscape 20	A	C	B		B-
Riverscape 22	A	B+	B		B+
Riverscape 23	A	B+	B		B+
Riverscape 24	A	B+	B		B+

*Analysis of the timing of peak flow was done for a gaging station outside (upstream) of the Middle Yampa Segment (the Yampa River at Steamboat). Because several major tributaries enter the Yampa between this gage location and the Middle Yampa segment, the shifting peak analysis was incorporated holistically into overall scores for all 7 riverscapes.

2.2 SNOWPACK INDICATOR

Much of the Yampa Basin is currently a snowmelt-driven system, meaning that the majority of river flows are derived from a melting snowpack in the springtime as opposed to rainfall or groundwater. In a snowmelt-driven system, snowpack characteristics have a direct effect on the basin's overall flow regime. This indicator considers maximum snowpack depth and associated maximum snow-water equivalent volume, timing of maximum snowpack, and timing from maximum snowpack to peak runoff.

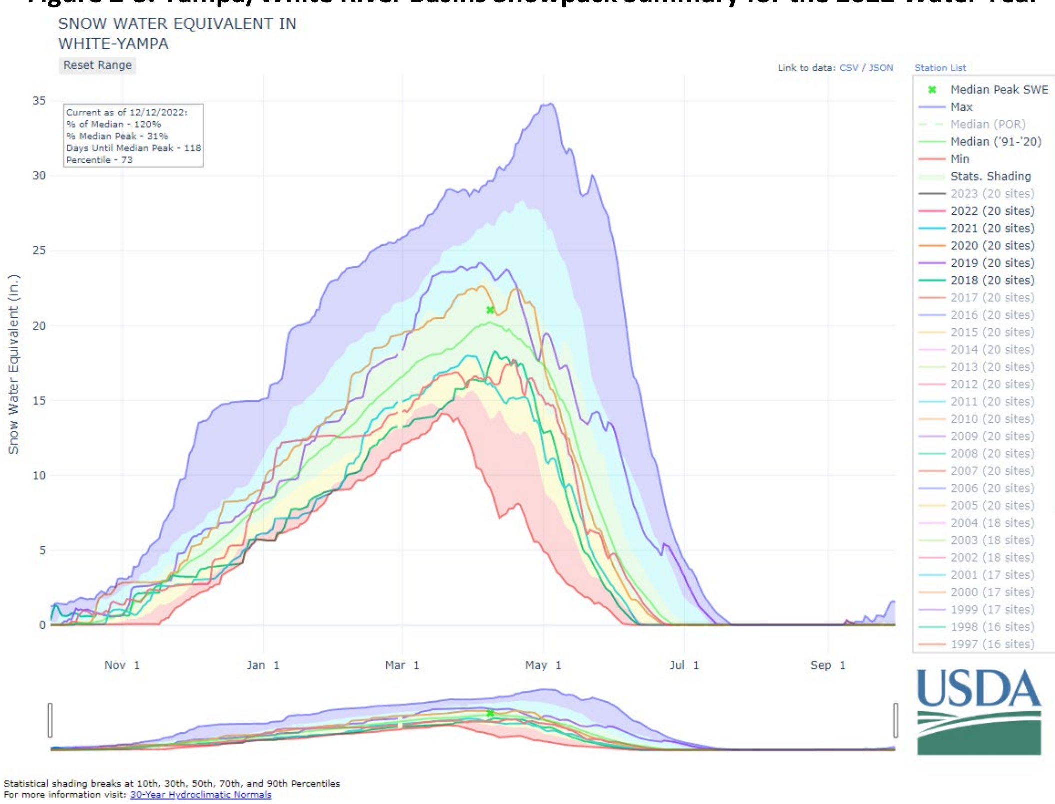
2.2.1 Data Sources and Evaluation Methods

Snowpack data (in the form of snow water equivalent, or SWE) is collected and shared by the Natural Resources Conservation Service (NRCS) collectively for the Yampa and White River Basins. The NRCS typically compares SWE amounts and timing to the 30-year average and median curves (Figure 2-3). However, in using the NRCS dataset, the Yampa River Scorecard Project obtained data for the entire period of record instead of limiting the analysis to the most recent 30-year average. It also reviewed the locations of SNOTEL sites that generate the SWE data to ensure they are located in the contributing watershed for the focal segment.

This indicator is evaluated as follows:

(1) Calculate the mean, 95% confidence interval, and standard deviation for maximum SWE (inches) for the period of record;
(2) Calculate the mean, 95% confidence interval, and standard deviation for timing of maximum snowpack (Julian date) for the period of record;
(3) Calculate the date of peak runoff for the USGS 09247600 YAMPA RIVER BELOW CRAIG, CO stream gauge for each year since 1984, and calculate the number of days from maximum snowpack to peak runoff;
(4) Calculate the mean, 95% confidence interval, and standard deviation for maximum snowpack to peak runoff (number of days) for the period of record; and
(5) Review these statistics in light of scoring criteria to rate this indicator for the most recent 5-year period for which data are available.

Figure 2-3. Yampa/White River Basins Snowpack Summary for the 2022 Water Year



2.2.2 Scoring Criteria

The semi-quantitative scoring criteria outlined in Table 2-3 are used to rate the snowpack indicator. Current conditions are considered to be the last five years of data, and the entire period of record for each SNOTEL site used in the analysis is provided in Table 2-4.

Table 2-3. Snowpack Indicator Scoring Criteria

Grade	Description
A	Current snowpack is within the range of historical conditions. Maximum snow-water equivalent (SWE) volume is within the 95% confidence interval (CI) of the period of record. Timing of maximum SWE is within the 95% CI of the period of record. Timing from maximum SWE to peak runoff is within the 95% CI of the period of record.
C	Current SWE volume is within one standard deviation of the period of record. Timing of maximum SWE is within one standard deviation of the period of record. Timing from maximum SWE to peak runoff is within one standard deviation of the period of record.
F	Current SWE volume is greater than one standard deviation from the period of record. Timing of maximum SWE is greater than one standard deviation from the period of record. Timing from maximum SWE to peak runoff is greater than one standard deviation from the period of record.

2.2.3 Results

Eight SNOTEL sites that generate SWE data are located within the contributing watershed for the focal segment (Figure 2-4). Substantial heterogeneity exists in the length of the period of record for each station (Table 2-4), which ranges from 6 years at Elkhead Divide to 44 years at Elk River and Tower.

Figure 2-4. Locations of Middle Yampa River Segment Contributing Watershed SNOTEL Sites

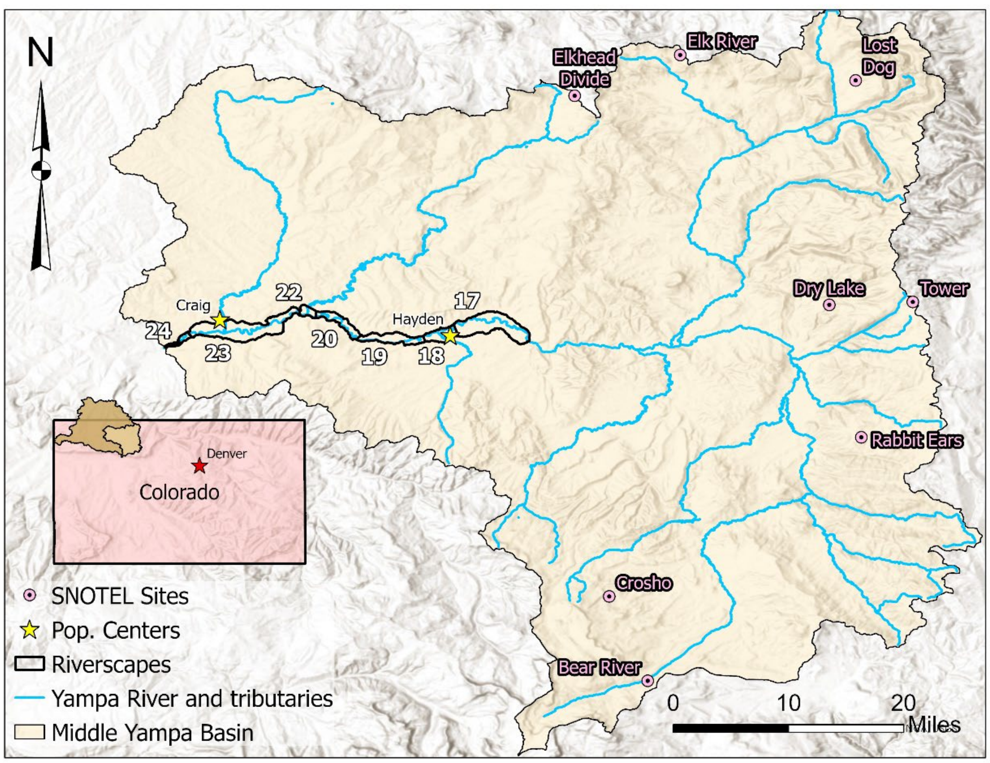


Table 2-4. Middle Yampa River Segment Contributing Watershed SNOTEL Site Details

Station	Start Year*	End Year	Elevation (ft)
Elkhead Divide	2016	2022	8,801
Bear River	2004	2022	9,113
Lost Dog	1998	2022	9,329
Crosho	1985	2022	8,975
Rabbit Ears	1985	2022	9,411
Dry Lake	1979	2022	8,273
Elk River	1978	2022	8,742
Tower	1978	2022	10,622

*Data begin with first snow of the denoted start year (generally in October)

Figure 2-5 compares the maximum annual SWE volume for the past 5 years of data (2018-2022) to the long-term mean (dashed line), 95% confidence interval (dark gray), and standard deviation (medium gray) generated from the period of record data. Maximum SWE volume over the last five years is generally within a single standard deviation of the period of record mean but outside of the 95% confidence interval (CI) (Figure 2-5). Over the last two years, SWE volume is significantly below the mean (i.e., outside the 95% CI) at all SNOTEL stations, though still within a single standard deviation of the mean at 6 of 8 stations (2021 at Rabbit Ears and Tower are the sole exceptions). SWE volume during the winter of 2019 and 2020 was within the 95% CI at half of the eight stations; for just 2020, this increases to 7 of 8 (Bear River was above the 95% CI), while for 2019 it is true of 5 of the 8, with SWE at the remaining eight significantly above the mean but still within a single standard deviation. Notably, all of these observed departures are greater than the mean trend. For 2018, all stations save Elkhead Divide and Bear River had maximum SWE volumes significantly below the mean though still within a single standard deviation. Scores range from A to C for a given station for a given year; the Elkhead Divide station earns the overall highest grade, but this is likely a function of the short-term dataset at this location rather than reflective of a healthier snowpack than average (Table 2-4). The overall lowest scores for SWE volume occur at Rabbit Ears, Dry Lake, and Tower. Notably, these sites are clustered fairly close together at the southern end of the Park Range.

Figure 2-5. Maximum Annual SWE Volume (2018-2022) Compared to Long-Term Data

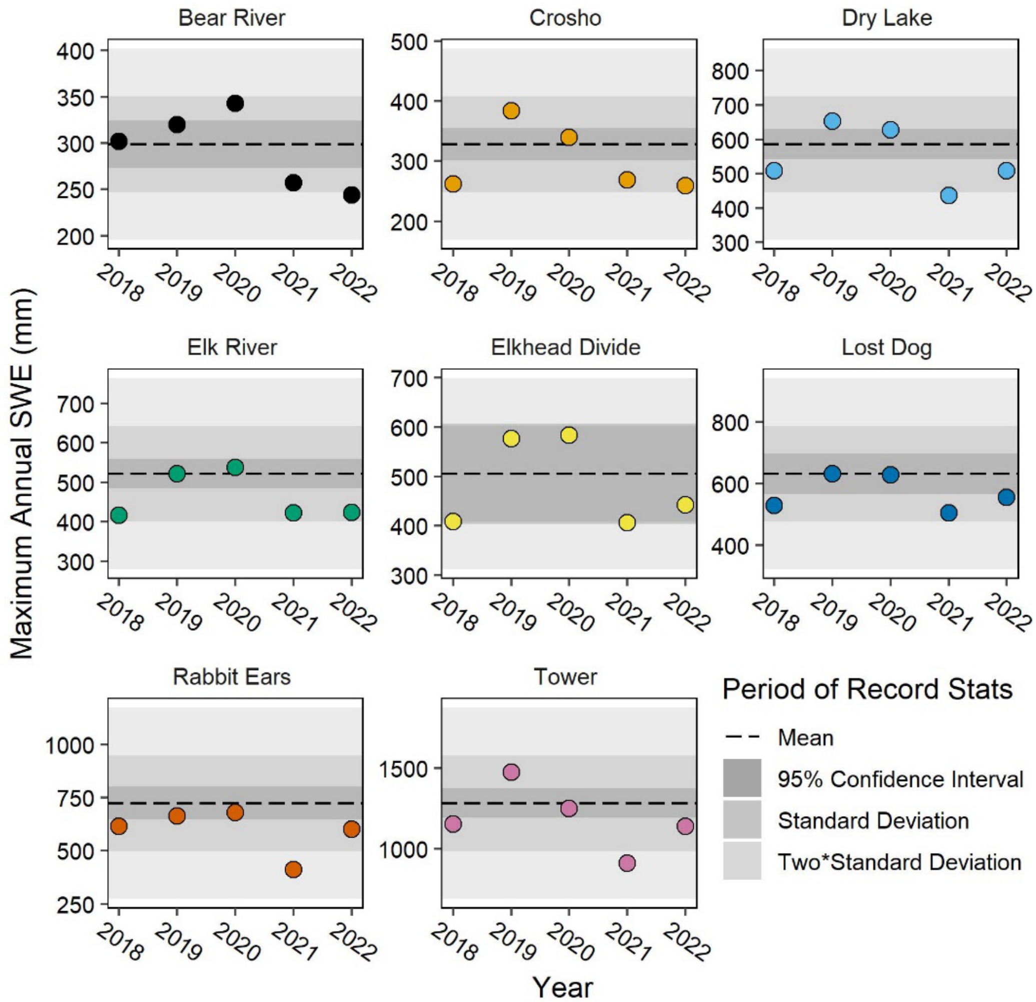
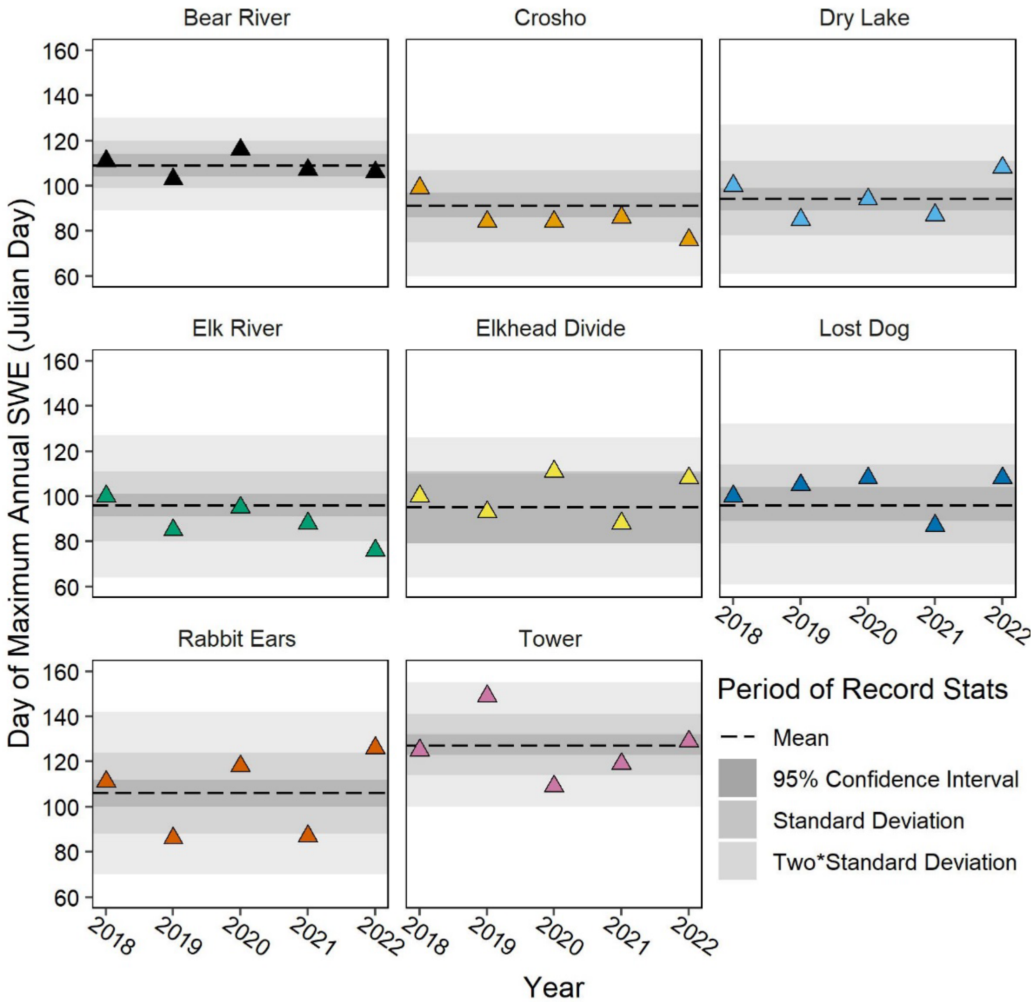


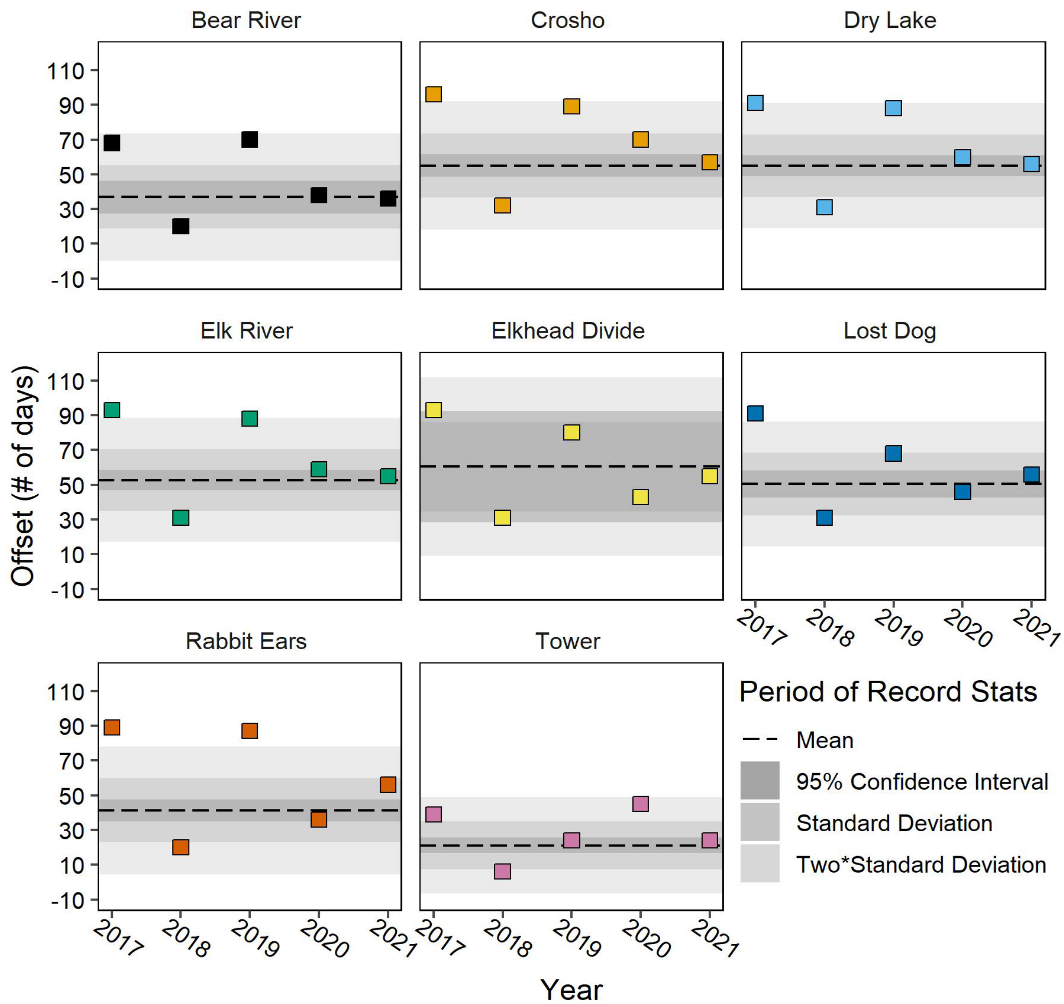
Figure 2-6 shows the timing of maximum annual SWE volume (day of year) for the past five years of data compared to the long-term mean (dashed line), 95% confidence interval (dark gray), and standard deviation (medium gray) generated from the period of record data. Timing of maximum SWE displays few observable patterns outside of 2018, when the day of maximum SWE was not significantly different than the overall mean at all stations (Figure 2-6). Overall, timing of maximum SWE is within a single standard deviation of the mean for all years at 5 of the 8 SNOTEL stations. The exceptions are Tower, Rabbit, and Elk River, which have one (Tower and Elk River) and tow (Rabbit) years that fall below a single standard deviation (though within two standard deviations) of the mean. These stations thus earn the lowest grades (Table 2-5).

Figure 2-6. Timing of Maximum Annual SWE Volume (2018-2022) Compared to Long-Term Data



Finally, the length of time (i.e., offset) between the timing of peak SWE and the timing of peak streamflow is noticeably different over the most recent five years than the mean for the period of record at each site (Figure 2-7). In general, the offset in 2017, 2018, and 2019 was significantly different than the period of record at all stations; 2020 and 2021 were more similar. Scores for this indicator range between B+ and D. (Table 2-5).

Figure 2-7. Offset of Maximum Annual SWE Volume and Peak River Discharge (2018-2022) Compared to Long-Term Data



Despite variability between stations, the SNOTEL stations scored a C for overall score on average; as a result, the snowpack indicator overall receives a score of C for all riverscapes in the Middle Yampa River segment (Table 2-5).

Table 2-5. Snowpack Indicator Scores by SNOTEL Station

Station	Max Score	Timing Score	Offset Score	Overall Score
Bear River	B	A	B	B+
Crosho	C	B+	D	C
Dry Lake	C	B	C	C
Elk River	C	C	C	C
Elkhead Divide*	A-	A-	B+	A-
Lost Dog	C+	B+	D	C-
Rabbit Ears	C	D	C	C-
Tower	C	C	C	C
Middle Yampa Segment (All Riverscapes)	C			

*Note: The Elkhead Divide SNOTEL station has only a six-year period of record. It is thus considered with relatively lesser weight than the other stations with regards to the overall score.

3.0 SEDIMENT REGIME

Sediment regime is defined as the amount and timing of sediment that all sources, including land erosion in the contributing watershed and upstream channel erosion, supply to a reach, as well as patterns of sediment transport along and out of a reach. The production, transport, and deposition of sediment largely determines channel form and dynamics. Like changes to flow regime, an altered sediment regime can cause significant impacts to stream form and function, including aquatic habitat quality and long-term channel stability, and can damage infrastructure. The Yampa River Scorecard evaluates the system's sediment regime holistically, using a single indicator referred to as **sediment transport and continuity**.

3.1 SEDIMENT TRANSPORT AND CONTINUITY INDICATOR

The sediment transport and continuity indicator considers the ability of the system to maintain natural transport of sediment from its upstream and upgradient sources. In the Yampa River Scorecard Project, this indicator is scored holistically and qualitatively. While sediment transport capacity is predominantly controlled by stream discharge and slope, the number and size of natural and unnatural impediments to sediment transport and the proportion of the reach and watershed from which sediment transport is blocked have a significant impact.

3.1.1 Data Sources and Evaluation Methods

This indicator is scored using expert interpretation of stressors affecting sediment transport. Scoring is based on field observations, aerial imagery, and GIS spatial data (Appendix A). Signs of sediment aggradation or degradation include disproportionate bar formation, increased bar stabilization, embeddedness by fine-grained material, disproportionate erosion, rapid meander migration, an incised channel with collapsing banks, and/or development of an inset floodplain. Field assessments are completed where appropriate to gain information about streambed substrate composition, stream power, sedimentation, embeddedness, and armoring. The Scorecard public interface plans to explain in layperson terms that erosion and deposition are natural processes that are both critical to maintaining a healthy system, using examples of cottonwood and willow riparian galleries relying on bank erosion and its associated bar and substrate deposition, and bank stabilization practices to limit erosion that just propagate the impact downstream. The Scorecard also intends to present river stability as a continuum that can be affected by sediment loads, which may lead to either erosion or deposition, but may not necessarily make the river an "unhealthy" one.

3.1.2 Scoring Criteria

Table 3-1 includes the narrative criteria used to rate the sediment transport and continuity indicator. The criteria relate primarily to impediments to sediment transport, signs of sediment balance (or imbalance), and also to the presence of stressors and level of maintenance required to maintain functional river processes.

Table 3-1. Sediment Transport and Continuity Indicator Scoring Criteria

Grade	Description
A	The amount of sediment transported through the reach is optimized to maintain self-sustainable balance with no management or maintenance required. There are only limited, if any, impediments to sediment delivery or transport throughout the reach. Minimal signs of sediment imbalance or disequilibrium are evident.
B	Impediments to sediment transport may exist, but they are either insignificant or they impact sediment balance from only a small portion of the overall contributing area. Minor stressors are present and minimal management or maintenance is required to maintain functionality. Limited signs of sediment imbalance or disequilibrium are evident.
C	Impediments to sediment transport through the reach are notable and are impacting the sediment balance a moderate portion of the reach. Maintenance and management are required to maintain functionality. Moderate signs of sediment imbalance or disequilibrium are evident.
D	Major impediments to sediment transport exist, yet these impediments either pass a portion of the sediment downstream or block sediment from less than half of the reach. Stressors significantly alter the natural sediment balance, and extensive or consistent active management and maintenance are required. Ample signs of sediment imbalance or disequilibrium are evident.
F	Severe impediments to sediment transport are present and impact most or all of the reach. The sediment balance through the reach is severely altered to a level that results in an inability to support functional processes. Signs of sediment imbalance or disequilibrium are ubiquitous.

3.1.3 Results

The sediment transport and continuity indicator is evaluated through field observations and remote sensing analysis using aerial imagery and GIS spatial data. Review of additional documents, specifically a 2021 USGS report of water quality in the Upper Yampa Basin (Day 2021) and the Yampa River Basin Remote Assessment (Yampa IWMP 2021), was also completed in order to further augment the analysis.

To begin to investigate the state of the sediment regime of the Yampa River, historical aerial imagery spaced at regular intervals (Table 3-2) was analyzed in order to examine temporal trends in channel dimensions (Jagt et al. 2022). Because rivers are scaled to the water and sediment loads they carry, detectable trends in channel dimensions across time suggest perturbations in either component over that same time period. A significantly narrower channel today than in the past, for example, could potentially indicate a disruption in sediment supply that has resulted in observable channel adjustments as the river seeks to establish a new equilibrium. Channel widths were measured at regular spaced intervals of 0.5 miles (0.8 km) spacing; this was done for each year of historical imagery. Box plots of widths for each riverscape at each timestep were then constructed to examine temporal differences; this visual inspection was complemented by statistical tests (Welch’s t-tests) to detect significant differences between years (Figure 3-1).

In all riverscapes except riverscape 17, no significant difference is observed in channel dimensions across the three twenty to twenty-five year intervals examined (1953 to 1977, 1977 to 1999, and 1999 to 2019) (Figure 3-1). In riverscape 17, the channel widened significantly (p-value = 0.02) from 1953 to 1999, but then subsequently narrowed to where present-day (2019) dimensions are not significantly different than those in 1953. Overall, the lack of significant temporal trends in channel width – especially in conjunction with the lack of observable change in peak flows – suggests that the Yampa River retains a healthy sediment regime. Similarly, few other obvious indicators of sediment disequilibrium exist; little evidence of disproportionate bank erosion or incision was found on the Colorado Mountain College field course float of the study segment that was conducted in June 2021. Deposition and erosion indicative of healthy river (e.g., meandering) were also observed in several locales (e.g., Appendix A, Figures A-10 through A-14). Embeddedness is additionally low (<10%) or moderate (10-20%) at sampling sites in six of the seven riverscapes (refer to Section 9.2 for more information).

Table 3-2. Historical Images Used in Width Analysis

Year	Image Count	Scale
1953	5	1:62540
1977	9	1:24000
1999	7	1:40000
2019	21	1:40000

However, several barriers to longitudinal (downstream) transport exist. Because such barriers may restrict the downstream movement of sediment, potentially starving the more downstream reaches, they represent a stressor to the health of the sediment regime. In-channel barriers are concentrated predominantly in the upper and lower riverscapes of the study segment (riverscapes 17 and 18; riverscapes 23 and 24) and generally take the form of either "push-up" dams for irrigation infrastructure or transportation (railroad/highway) bridge crossings (refer to Section 5.1 for more information). Scores for the sediment regime indicator in the upper and lower riverscapes thus are detrimentally impacted by the existence of these structures (Table 3-3). Riverscapes 23 and 24, where barriers to both downstream transport of sediment and lateral transport onto the floodplain are substantial (refer to Section 5.1), receive the lowest scores.

Finally, a USGS investigation of suspended sediment data at the Yampa River above Elkhead gage indicates that no temporal trend in sediment concentration exists for the period from 1990-2018 (Day 2021). Similarly, analysis associated with the Yampa River Remote Assessment suggests that there are no detectable trends in gravel bar densities for a roughly similar time period (Yampa IWMP 2021). Together, these analyses converge on the idea that the sediment regime through the Middle Yampa segment has remained steady over the better part of the last three decades; combined with the above analysis of historical imagery dating back to the 1950s, it can reasonably be concluded that such stationarity extends over roughly seventy years. Though the possibility does exist that appreciable changes to the sediment regime of the Yampa River occurred prior to the period of record analyzed here, the relative dearth of detrimental features (e.g., rapidly incision and collapsing banks) and lack of any recent generalizable temporal trends indicate that the Yampa River has a relatively healthy sediment regime.

Figure 3-1. Box Plots of Channel Widths for Each Set of Historical Aerial Images

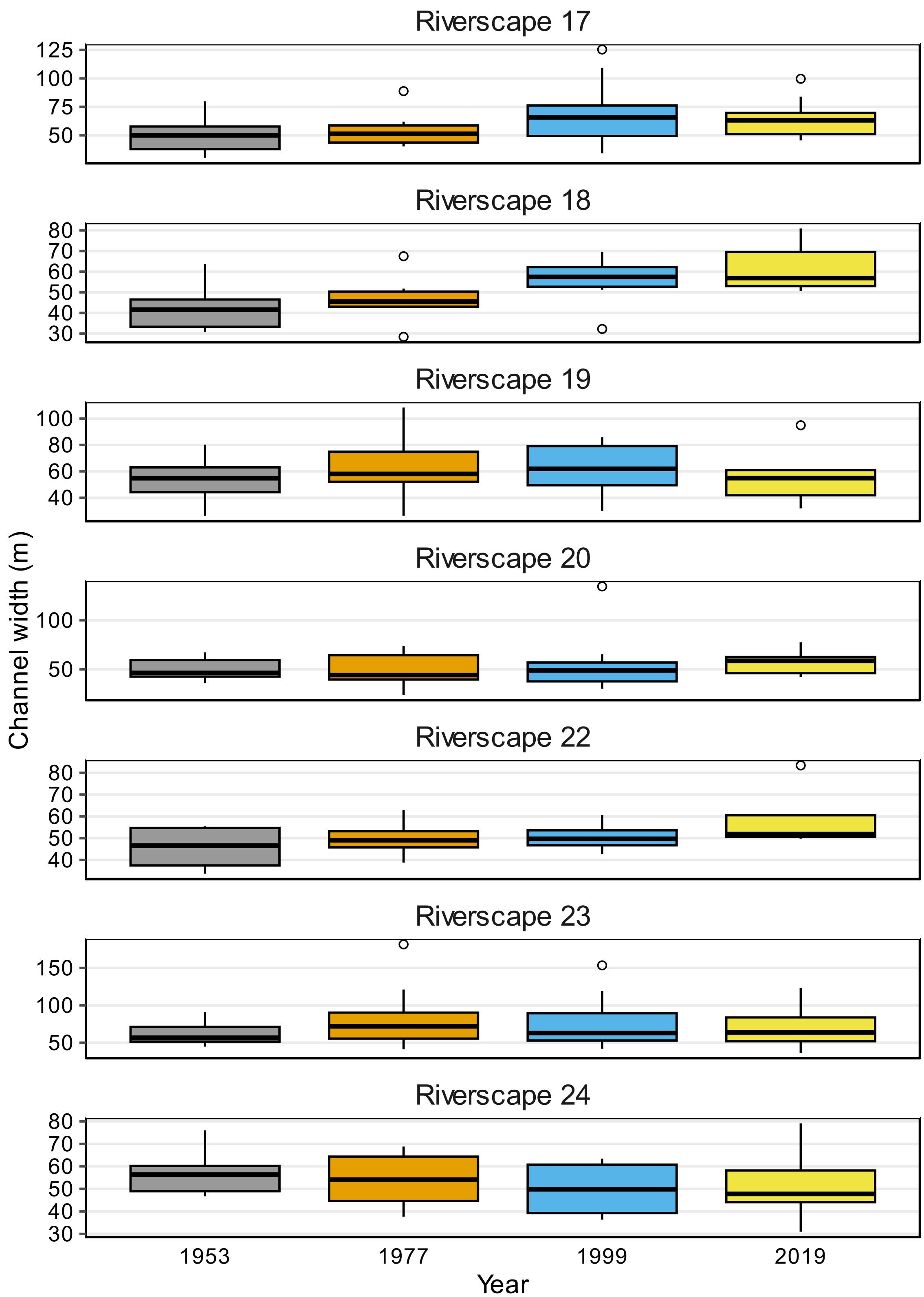


Table 3-3. Sediment Transport and Continuity Indicator Scores by Riverscape

Riverscape	Sediment Transport/Continuity Score
Riverscape 17	A-
Riverscape 18	A-
Riverscape 19	A
Riverscape 20	A
Riverscape 22	A
Riverscape 23	B-
Riverscape 24	B-

4.0 WATER QUALITY

Water quality is defined as the physico-chemical characteristics of water in a river segment, and it is influenced by natural geological weathering, biogeochemical processes, and human activities (upstream land and water uses). Suitable water quality in streams supports recreational uses, ensures public health, and supports wildlife and fish habitat. The Yampa River Scorecard uses several indicators to evaluate water quality. The list of indicators is based on feedback from the Technical Committee and contains parameters that are relatively easy to measure and/or for which data already exist. The six water quality indicators are **temperature, dissolved oxygen, pH, macroinvertebrates, nutrients, and metals**. The final water quality score is calculated as an average of the six indicator scores.

Water quality measurements that can be important for assessing stream health include parameters that fall into the following categories: (1) standard physical parameters that can be measured *in situ* with a handheld water quality instrument that provides instantaneous results (e.g., temperature, pH, conductivity, dissolved oxygen, oxidation-reduction potential, turbidity); (2) analytes that require water samples to be collected and sent to a laboratory for analysis (e.g., total and dissolved metals, nutrients); and (3) biological indicators of water quality (e.g., macroinvertebrates). This section provides more detail on the six indicators included in the Yampa River Scorecard.

4.1 TEMPERATURE INDICATOR

Water temperature is measured using a standard water quality meter or a thermometer. The ranges of many aquatic species are limited by temperature, so this parameter is an important measure of habitat quality. Shading from the riparian canopy, good hyporheic exchange, and seepage from spring-fed tributaries (in some cases) contribute to lower temperatures that support the cool- and cold-water fish species present in Colorado streams and rivers. The Scorecard focal segment is located in a transition zone between cold-water and warm-water fisheries, so temperatures are expected to increase naturally in a downstream direction. The CDPHE Stream Classifications for Aquatic Life are as follows:

- Yampa mainstem from Oak Creek to Elkhead Creek: Cold Water I with temporary modification
- Yampa mainstem below Elkhead Creek: Warm Water I

Instantaneous measurements of water quality taken manually have limited value when considering optimal conditions for resident aquatic species. Continuous temperature data loggers that collect temperature measurements at regular intervals provide a greater understanding of the conditions impacting aquatic habitat. These are relatively inexpensive but can be tricky to install in a system like the Yampa River Basin that sees large fluctuations in flows, freezing during winter months, visitation by curious individuals or animals, and other challenging conditions for field monitoring.

4.1.1 Data Sources and Evaluation Methods

Instantaneous temperature measurements are collected quarterly by USGS at the Yampa River above Elkhead Creek and Yampa River below Craig stream gage and monitoring locations, but otherwise continuous temperature measurements are not currently being collected in the focal segment. From March 2012 through December 2014, CDPHE maintained a continuous temperature monitor at the Dorsey boat launch location in the Yampa State Wildlife Area (Site #3 in Figure 1-1). For the Scorecard project, two continuous temperature monitoring devices, one upstream and one downstream of the Elkhead Creek confluence, were installed in July 2021 so that 2021-2022 temperature data can be used to score this indicator. Continuous temperature monitoring sensors were installed at the Dorsey boat launch upstream of Elkhead Creek, and at the Craig intake structure downstream of Elkhead Creek. Temperature data loggers deployed as part of the Scorecard effort follow the same protocols for equipment installation and retrieval as the City of Steamboat Springs in order to maintain consistency across the Yampa basin; additional details are provided in the Yampa River Scorecard Project Indicators and Methods Report (FOTY/Alba Watershed Consulting 2021).

4.1.2 Scoring Criteria

The temperature indicator scoring criteria outlined in Table 4-1 are based on regulatory standards. These criteria are not quantitative; rather, they rely on consulting current regulatory standards. This is because of the transition between aquatic use classifications of cold water and warm water upstream and downstream of the Elkhead Creek confluence, respectively, as well as the current (through 2024) temporary modification of the chronic temperature standard upstream of Elkhead Creek based on data collected by the City of Steamboat Springs.

Table 4-1. Temperature Indicator Scoring Criteria

Grade	Description
A	Temperature regime is natural and appropriate for a well-functioning river in its process domain.
B	Temperature regime is within the range of natural variability. Natural aquatic biota are minimally impaired. Regulatory standards are not exceeded.
C	Temperature regime is altered to a degree that could significantly affect natural aquatic biota. Regulatory standards are occasionally exceeded. CDPHE Monitoring and Evaluation (M&E) listed reaches fall in this category.
D	Temperature regime is altered to a degree that is known to affect natural aquatic biota. Regulatory standards are frequently exceeded. CDPHE 303(d) listed reaches fall in this category.
F	The temperature regime is fundamentally altered. Natural biota are severely impaired. Regulatory standards are chronically exceeded.

4.1.3 Results

The temperature indicator is evaluated through the analysis of approximately 13 months of temperature data collected at 30-minute intervals via continuous temperature sensors installed for this project on July 15, 2021 at two locations in the focal segment: the Yampa River at Dorsey, located in riverscape 20, and the Yampa River at Craig Intake, located in riverscape 23. Data analyzed here run from July 15, 2021 to August 8, 2022. Results were evaluated against current regulatory standards, primarily the daily maximum (DM) temperature or acute standard, which regulates the maximum temperature that can occur over a 24-hr period, and the maximum weekly average temperature (MWAT) or chronic standard, which sets the maximum allowable temperature for the rolling 7-day mean of daily average temperature.

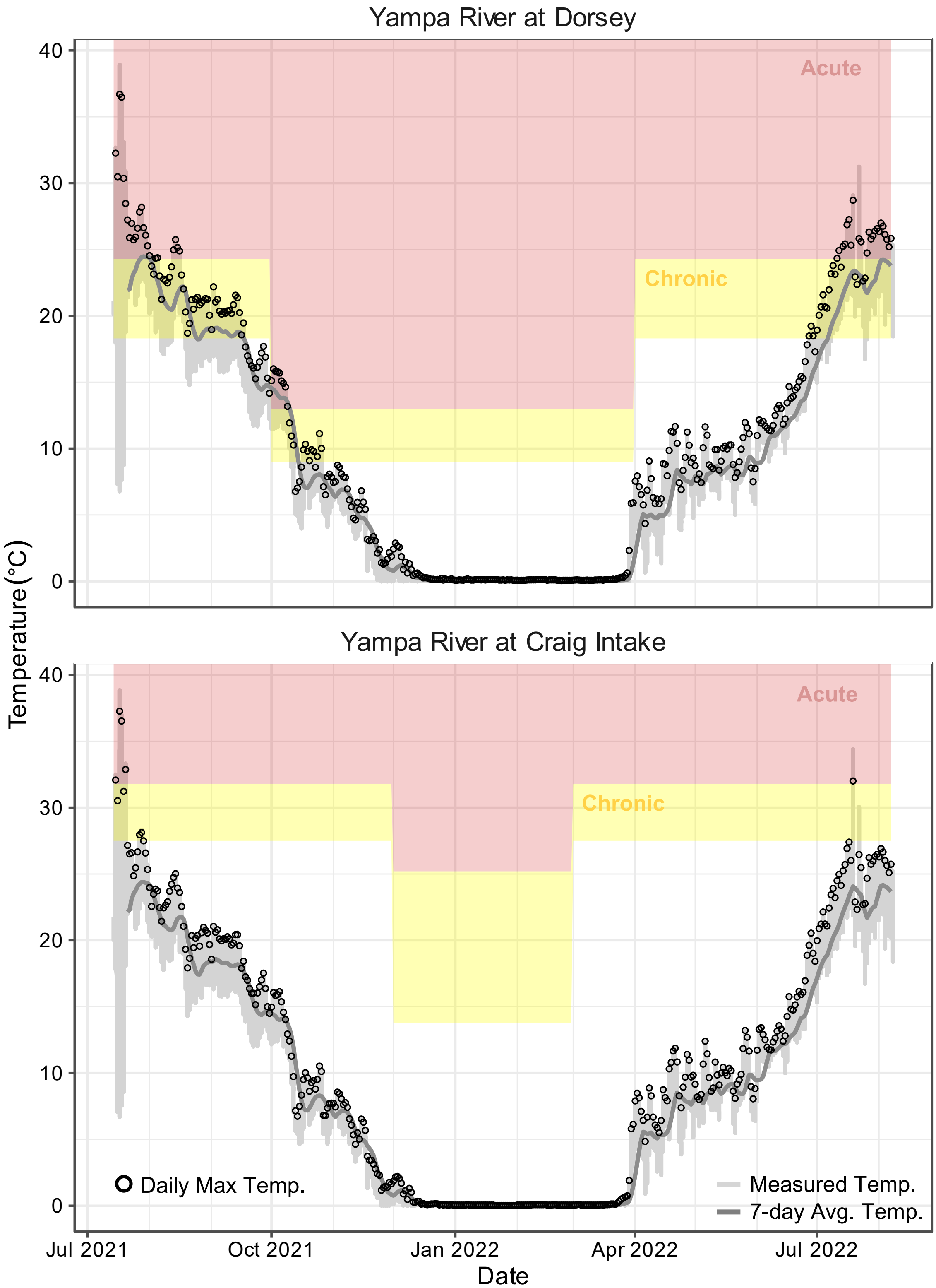
At Dorsey, maximum daily temperatures are consistently above regulatory DM standards in the late summer months (July and August) through mid-September and then again for the month of October (Figure 4-1). Similarly, average weekly temperature exceeds the MWAT temporary standard (18.3 ^{o}C for July-September) in July and much of August, as well as in early October. This is consistent with the 303(d) listing of this segment of the Yampa (i.e., riverscapes 17, 18, 19, and 20) for temperature. Riverscapes 17-20 earn a score of D (Table 4-2).

In contrast, maximum daily temperature as recorded at the Craig Intake only exceed the standard (31.8 ^{o}C from July-November) for five days in July (four in 2021 and one in 2022) (Figure 4-1). Average weekly temperatures likewise only exceeded the MWAT regulatory standard for four days and one day in mid-July 2021 and 2022, respectively. Riverscapes 22-24 earn a score of B (Table 4-2).

Table 4-2. Temperature Indicator Scores by Riverscape

Riverscape	Temperature Score
Riverscape 17	D
Riverscape 18	D
Riverscape 19	D
Riverscape 20	D
Riverscape 22	B
Riverscape 23	B
Riverscape 24	B

Figure 4-1. Continuous Temperature Data for Yampa River at Dorsey and Yampa River at Craig Intake Locations (July 2021 – August 2022)



4.2 DISSOLVED OXYGEN INDICATOR

Dissolved oxygen (DO) is the amount of free oxygen present in the water column and is important for the survival of fish and other aquatic species. To ensure accurate readings when using a water quality meter to record DO, the meter must be suspended in the water column and out of direct contact with the stream bed, which is sometimes difficult in shallow streams.

4.2.1 Data Sources and Evaluation Methods

Field-based water quality parameters including dissolved oxygen are measured quarterly by USGS as part of the Upper Yampa River Basin Water Quality Monitoring Program. Two locations in the Scorecard focal segment are part of this monitoring program: Yampa River Above Elkhead Creek Near Hayden, CO and Yampa River below Craig, CO. Data were downloaded from nwis.waterdata.usgs.gov. FOTY also collected two water quality samples at the Craig Intake location (riverscape 23) in 2022: one in June during high-flow conditions, and one in September during low-flow conditions.

4.2.2 Scoring Criteria

Similar to temperature, the dissolved oxygen scoring criteria outlined in Table 4-3 are based on regulatory standards.

Table 4-3. Dissolved Oxygen Indicator Scoring Criteria

Grade	Description
A	Dissolved oxygen concentrations are natural and appropriate for a well-functioning river in its process domain.
B	Dissolved oxygen concentrations are within the range of natural variability. Natural aquatic biota are minimally impaired. Regulatory standards are not exceeded.
C	Dissolved oxygen concentrations are altered to a degree that could significantly affect natural aquatic biota. Regulatory standards (6.0 mg/L or 5.0 mg/L) are occasionally exceeded. CDPHE Monitoring and Evaluation (M&E) listed reaches fall in this category.
D	Dissolved oxygen concentrations are altered to a degree that is known to affect natural aquatic biota. Regulatory standards (6.0 mg/L or 5.0 mg/L) are frequently exceeded. CDPHE 303(d) listed reaches fall in this category.
F	Dissolved oxygen concentrations are fundamentally altered. Natural biota are severely impaired. Regulatory standards are chronically exceeded.

4.2.3 Results

The dissolved oxygen indicator is evaluated through review of USGS Water Quality Monitoring Program data at the Yampa River Above Elkhead Creek Near Hayden, CO and Yampa River below Craig, CO monitoring locations. Because rivers integrate upstream inputs, data from the above Elkhead station (located in riverscape 20) are used to score riverscapes 17, 18, 19, and 20; data from the below Craig station (located in riverscape 24) are used to score the remaining riverscapes (22, 23, 24).

Dissolved oxygen concentrations at both the above Elkhead and below Craig station are well above the standard for aquatic life for each location (Figure 4-2). Given the relative lack of pollutants and despite observations of algal growth, this is relatively unsurprising, yet also encouraging. Each riverscape is scored an A in this regard (Table 4-4).

Figure 4-2. Dissolved Oxygen Concentrations from Quarterly Water Sampling at the Yampa River above Elkhead Creek and Yampa River below Craig, CO Locations (2010-2022)

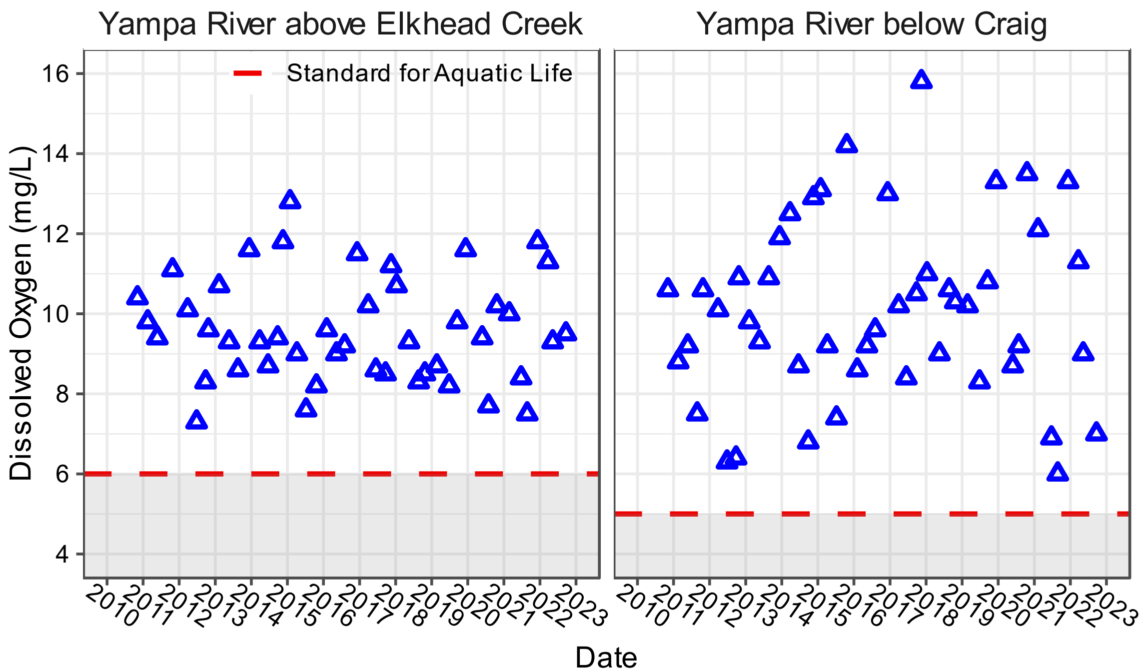


Table 4-4. Dissolved Oxygen Indicator Scores by Riverscape

Riverscape	Dissolved Oxygen Score
Riverscape 17	A
Riverscape 18	A
Riverscape 19	A
Riverscape 20	A
Riverscape 22	A
Riverscape 23	A
Riverscape 24	A

4.3 pH INDICATOR

pH is a measure of water acidity that runs on a scale from 0 to 14, where lower numbers indicate high acidity, pH 7 is neutral, and higher numbers indicate water that is more basic. The ranges of many aquatic species are limited by pH.

4.3.1 Data Sources and Evaluation Methods

Field-based water quality parameters including pH are measured quarterly by USGS as part of the Upper Yampa River Basin Water Quality Monitoring Program. Two locations in the Scorecard focal segment are part of this monitoring program: Yampa River Above Elkhead Creek Near Hayden, CO and Yampa River below Craig, CO. Data were downloaded from nwis.waterdata.usgs.gov. FOTY also collected two water quality samples at the Craig Intake location (riverscape 23) in 2022: one in June during high-flow conditions, and one in September during low-flow conditions.

4.3.2 Scoring Criteria

Similar to temperature and dissolved oxygen, the scoring criteria for pH outlined in Table 4-5 are based on adherence to regulatory standards.

Table 4-5. pH Indicator Scoring Criteria

Grade	Description
A	pH values are natural and appropriate for a well-functioning river in its process domain.
B	pH values are within the range of natural variability. Natural aquatic biota are minimally impaired. Regulatory standards are met.
C	pH is altered to a degree that could significantly affect natural aquatic biota. pH values occasionally fall outside the range of regulatory standards (6.5 - 9.0). CDPHE Monitoring and Evaluation (M&E) listed reaches fall in this category.
D	pH is altered to a degree that is known to affect natural aquatic biota. pH values frequently fall outside the range of regulatory standards (6.5 - 9.0). CDPHE 303(d) listed reaches fall in this category.
F	pH is fundamentally altered. Natural biota are severely impaired. pH values chronically fall outside the range of regulatory standards.

4.3.3 Results

The pH indicator is evaluated through review of USGS Water Quality Monitoring Program data at the Yampa River Above Elkhead Creek Near Hayden, CO and Yampa River below Craig, CO monitoring locations. Because rivers integrate upstream inputs, data from the above Elkhead station (located in riverscape 20) are used to score riverscapes 17, 18, 19, and 20; data from the below Craig station (located in riverscape 24) are used to score the remaining riverscapes (22, 23, 24).

Similar to dissolved oxygen, pH values at each monitoring location are within the standards for aquatic life (6.5 – 9) for nearly all samples collected from 2010-2022, though pH values in exceedance of 9 were detected in two samples (one each in late 2015 and 2018) (Figure 4-3).

Overall, regulatory standards are regularly and consistently met and each riverscape earns an A is this regard (Table 4-6).

Figure 4-3. pH Values from Quarterly Water Sampling at the Yampa River above Elkhead Creek and Yampa River below Craig, CO Locations (2010-2022)

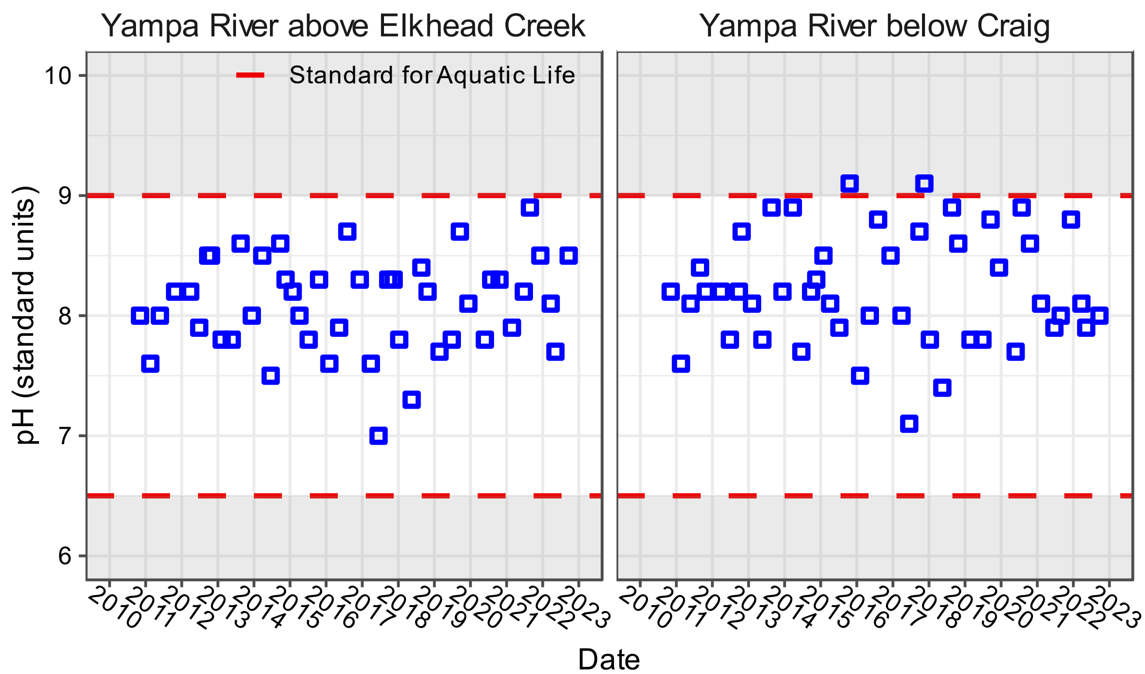


Table 4-6. pH Indicator Scores by Riverscape

Riverscape	pH Score
Riverscape 17	A
Riverscape 18	A
Riverscape 19	A
Riverscape 20	A
Riverscape 22	A
Riverscape 23	A
Riverscape 24	A

4.4 MACROINVERTEBRATES INDICATOR

Benthic macroinvertebrates are excellent indicators of the condition of lotic aquatic systems because macroinvertebrates are found in almost all freshwater environments, have a small home range, are relatively easy to sample and identify, and the different taxonomic groups show varying degrees of sensitivity to pollution and other stressors (CDPHE 2016a, Barbour et al. 1999). Benthic macroinvertebrate community monitoring is a useful tool for river health monitoring, particularly if baseline data are available.

Many comparative metrics may be used to assess the health of the benthic community, including the number of individuals; total number of taxa; total number of pollution-sensitive Ephemeroptera, Plecoptera, Trichoptera (EPT) taxa; ratios of different functional feeding groups or taxonomic groups; Shannon-Wiener Diversity Index (SDI); Hilsenhoff Biotic Index (HBI); and many others. The SDI is a mathematical measure of species diversity within a given community. For benthic macroinvertebrates, values range from 0-5, and higher values indicate higher species diversity (MacArthur 1965). The HBI reveals the relative abundance of pollution-tolerant species. Scores range from 0-10, where a higher value indicates more pollution-tolerant species are present (Hilsenhoff 1987).

The Colorado Department of Public Health and Environment (CDPHE) monitors streams throughout the state for assessment and protection of water resource quality. Their principal indicator is a multi-metric index (MMI) based on direct benthic macroinvertebrate sample data. By using five to six equally weighted metrics, the MMI combines measures of diversity, abundance, pollution tolerance, community structure, and other factors to generate a normalized score of 0-100 for each sample. Scores may then be compared to reference threshold scores for one of three generalized Colorado biotypes (mountains, transition, plains). In "grey" areas where the MMI alone is not sufficient, CDPHE also compares SDI and HBI results to attainment and impairment threshold values.

4.4.1 Data Sources and Evaluation Methods

Historical benthic macroinvertebrate data are scarce for the Yampa Scorecard focal segment. A small amount of data was collected in 2002 for Tri-State Generation and Transmission at two locations: upstream of Carpenter Ranch and in the vicinity of Craig. These data only include taxa identification and counts; no comparative metrics or summary statistics were calculated. Given the paucity of existing data, the relative ease of collecting and analyzing macroinvertebrate data, and the useful information that can be gleaned from these data, the Scorecard project provides a good opportunity for evaluating the macroinvertebrate community and tracking changes over time.

Seven benthic macroinvertebrate community samples were collected in the Middle Yampa segment for the Scorecard project effort: one in each of the seven riverscapes. Macroinvertebrate monitoring occurred during the low-flow period in early September 2022, and followed the SOP used by CDPHE for benthic macroinvertebrate sampling (CDPHE 2016). Detailed procedures for sample collection, processing, and preservation are provided in the SOP. Samples were collected with partners from River Watch and sent to Timberline Aquatics for taxonomic identification and data analysis.

4.4.2 Scoring Criteria

The scoring criteria outlined in Table 4-7 are currently based on adherence to regulatory standards set by CDPHE for the relevant biotype (biotype 1, transition) using mainly MMI scores and CDPHE-designated attainment and impairment thresholds. Because component metrics incorporated into the MMI are designed to detect water quality impairments and are less sensitive to changes in habitat, results of other comparative metrics are also taken into account during the scoring process.

Table 4-7. Benthic Macroinvertebrate Indicator Scoring Criteria

Grade	Description
A	The reach is considered to be representative of the expected condition for aquatic insect communities and aquatic life use for a well-functioning river in its process domain. No management is needed other than protection of existing conditions. MMI score is 80-100 and the reach is in attainment for aquatic life use (CDPHE 2016).
B	Some detectable stressors are evident with minor alterations to aquatic insect communities. The ecological system retains its overall structure and supports a high level of function. Some management may be required to sustain or improve this condition. MMI score is 61-79 and the reach is in attainment for aquatic life use (CDPHE 2016).
C	The reach supports and maintains essential components of the unimpaired aquatic insect community, but exhibits measurable signs of degradation and less than optimal community parameters. Management is required (or recommended) to maintain and improve this condition. MMI score is 46-60 and meets the CDPHE (2016) attainment threshold for aquatic life use.
D	Detectable alterations or degradation of aquatic life use are present, but the system still supports a fundamental aquatic insect community structure and function. Active management is required (or recommended) to maintain and improve characteristic functional support. MMI score is 34-45 and is considered to be in the “gray area” between aquatic life use attainment and impairment (CDPHE 2016).
F	Clear impairment to the aquatic insect community and aquatic life is present. This level of alteration generally results in an inability to support characteristic aquatic organisms, or makes the stream segment biologically unsuitable. MMI score is < 34 and aquatic life use is thus considered “impaired” (CDPHE 2016).

4.4.3 Results

The macroinvertebrates indicator is evaluated through analysis of data collected via the Scorecard project at one location per riverscape within the Middle Yampa segment (Figure 4-4). All samples collected within the Middle Yampa segment exhibited healthy and diverse macroinvertebrate communities, with total taxa ranging between 30 – 45 taxonomic groups, percent of pollution-tolerant taxa greater than 50% at all locations, high scores for species diversity, a well-balanced array of functional feeding groups, and MMI scores between 69.8 and 76.6 (Table 4-8, Figure 4-5). Furthermore, all riverscapes received the same score for the macroinvertebrate indicator as the overall measure of benthic community health was similar across all 7 riverscapes, and all scores were within 10 percent of each other (Table 4-9).

Figure 4-4. Map of Macroinvertebrate Sampling Locations

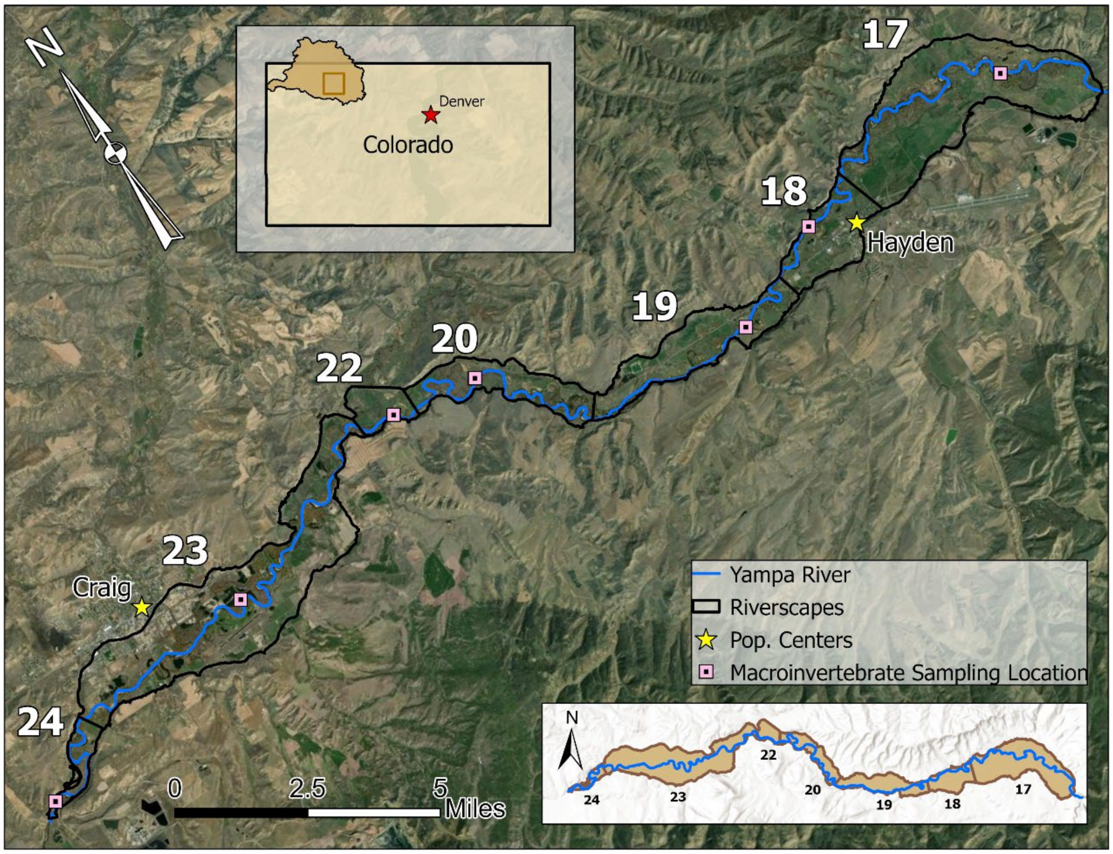


Table 4-8. Select Macroinvertebrate Metrics by Riverscape

Riverscape/Metric	RS 17	RS 18	RS 19	RS 20	RS 22	RS 23	RS 24
MMI v4	69.8	73.7	72.6	71.0	76.4	76.6	76.4
Diversity	4.32	3.74	3.81	3.23	3.53	3.30	3.39
Evenness	0.779	0.682	0.702	0.659	0.688	0.600	0.641
HBI	4.47	4.85	4.20	3.55	3.26	3.46	3.56
EPT	22	20	18	20	19	21	18
% EPT	64.4%	54.1%	62.1%	73.3%	73.2%	78.1%	77.9%
Total Taxa	47	45	43	30	35	45	39
% Chironomids	18.7%	23.0%	25.3%	5.5%	17.8%	10.7%	5.7%

Figure 4-5. Macroinvertebrate MMI Scores by Riverscape

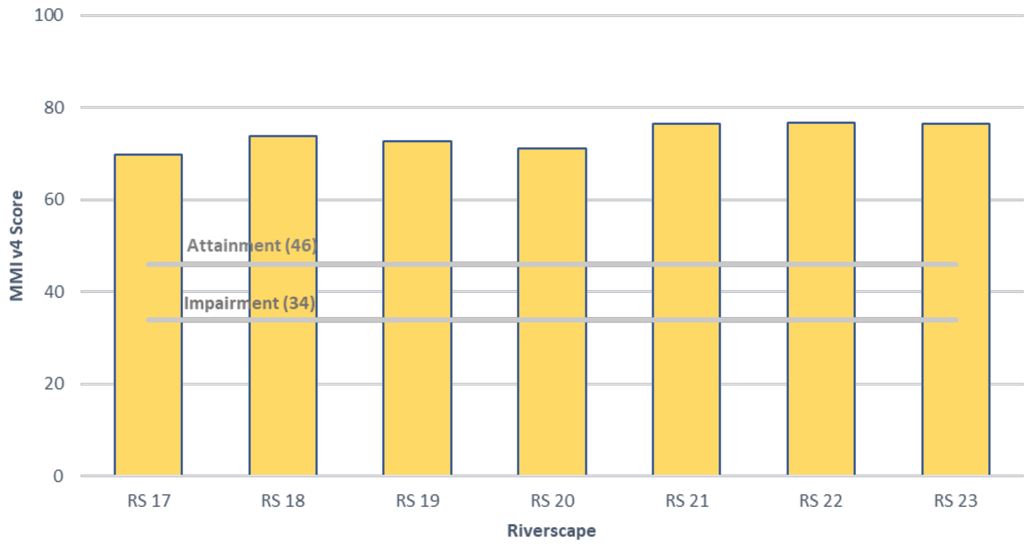


Table 4-9. Macroinvertebrate Indicator Scores by Riverscape

Riverscape	Macroinvertebrate Score
Riverscape 17	B+
Riverscape 18	B+
Riverscape 19	B+
Riverscape 20	B+
Riverscape 22	B+
Riverscape 23	B+
Riverscape 24	B+

4.5 NUTRIENTS INDICATOR

Nutrients in stream water are essential for plants and animals. They occur naturally due to processes such as weathering and erosion, breakdown of organic material, and atmospheric deposition, but high nutrient levels are not good for stream health. Elevated nutrient levels in surface waters can result from human activities such as fertilizer application, runoff from agricultural and urban areas, effluent from wastewater treatment, seepage from septic systems, detergent, animal waste, and fuel combustion. Elevated nutrient levels can also cause algal blooms. In the last decade, concerns about cyanobacteria and associated cyanotoxins have been expressed by stakeholders in the Yampa Basin as algal blooms have been reported in local lakes and reservoirs, so this indicator is of public interest and therefore important to evaluate for the Scorecard.

4.5.1 Data Sources and Evaluation Methods

Nutrients, including total nitrogen and phosphorus, are measured quarterly by USGS as part of the Upper Yampa River Basin Water Quality Monitoring Program. Two locations in the Scorecard focal segment are part of this monitoring program: Yampa River Above Elkhead Creek Near Hayden, CO and Yampa River below Craig, CO. Data were downloaded from nwis.waterdata.usgs.gov. FOTY also collected two water quality samples at the Craig Intake location (riverscape 23) in 2022: one in June during high-flow conditions, and one in September during low-flow conditions.

4.5.2 Scoring Criteria

The scoring criteria outlined in Table 4-10 based on adherence to interim regulatory standards set by CDPHE for nitrogen and phosphorus are used to rate the nutrients indicator.

Table 4-10. Nutrients Indicator Scoring Criteria

Grade	Description
A	Nutrient levels are natural and appropriate for a well-functioning river in its process domain.
B	Nutrient levels are within the range of natural variability. Natural aquatic biota are minimally impaired. Interim regulatory standards are not exceeded.
C	Nutrient levels are altered to a degree that could significantly affect natural aquatic biota. Interim regulatory standards (0.11 mg/L (cold) and 0.17 mg/L (warm) for total phosphorus; 1.25 mg/L (cold) and 2.01 mg/L (warm) for total nitrogen) are occasionally exceeded. CDPHE Monitoring and Evaluation (M&E) listed reaches fall in this category.
D	Nutrient levels are altered to a degree that is known to affect natural aquatic biota. Interim regulatory standards (0.11 mg/L (cold) and 0.17 mg/L (warm) for total phosphorus; 1.25 mg/L (cold) and 2.01 mg/L (warm) for total nitrogen) are frequently exceeded. CDPHE 303(d) listed reaches fall in this category.
F	Unnaturally eutrophic or oligotrophic conditions clearly affect the distribution and abundance of characteristic aquatic life. Interim regulatory standards have been exceeded consistently.

4.5.3 Results

The nutrients indicator is evaluated through review of USGS Water Quality Monitoring Program data at the Yampa River Above Elkhead Creek Near Hayden, CO and Yampa River below Craig, CO monitoring locations, where total phosphorus (TP), total Kjeldahl (organic) nitrogen (TKN), and total nitrogen T(N) have been measured quarterly since 2010. Because rivers integrate upstream inputs, data from the above Elkhead station (located in riverscape 20) are used to score riverscapes 17, 18, 19, and 20; data from the below Craig station (located in riverscape 24) are used to score the remaining riverscapes (22, 23, 24). A USGS analysis of nutrient data (both concentrations and loads) in the Upper Yampa Basin for the 1992-2018 period was completed in 2021; more specifically, this report analyzed nutrient data from 2010-2018 and 1999-2018 at the above Elkhead and below Craig sites, respectively. Scoring is based upon that analysis, the findings of which have been synthesized for the purpose of the Scorecard and are presented below (Day

2021), as well as additional examination of the data subsequent to the period covered in the USGS report (2019-2022). Particulars of the methodology used in the nutrient analysis that yielded the summarized results below can be found in the body of the referenced USGS report (Day 2021).

Total nitrogen (inorganic + organic nitrogen; TN) is measured quarterly by USGS at the sites mentioned above, as is Kjeldahl nitrogen (TKN). In the USGS report, daily concentrations of constituents are estimated from quarterly samples using linear regression models fit with R-LOADEST, a USGS-developed statistical program designed to calculate nutrient loads from periodic sampling data (see equation 1 of Day [2021] for mathematical explanation). Daily estimations of TN are not able to be made due to lack of the requisite number of samples; therefore, daily estimations of TKN are used as a surrogate for TN. Notably, daily estimations do not include quarterly sampling data from 2019-2022; rather, only the discrete data for this latter period were analyzed for the purposes of the Scorecard.

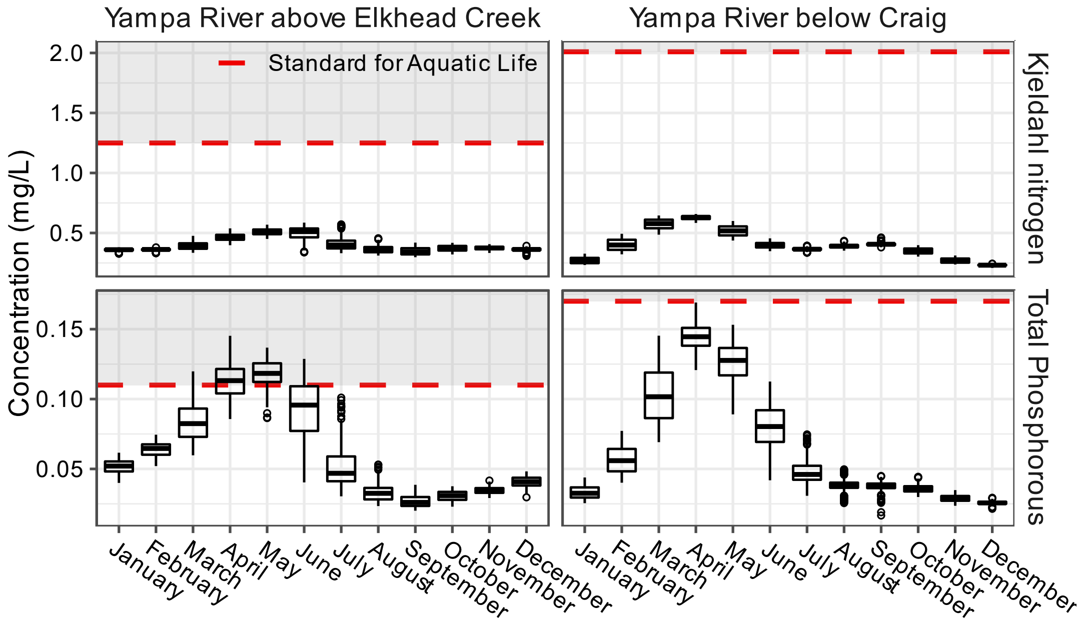
Estimated median annual TKN was well below the interim regulatory standard of 1.25 mg/L for cold water rivers (which applies to the above Elkhead station) and 2.01 mg/L for warm water rivers (which applies to the below Craig station) for all water years at both gaging stations in the study section (Table 4-11, Figure 4-6). Closer examination at a finer scale paints a similar picture: modeled daily and monthly median concentrations for TKN were also well below the regulatory standard for all days across the analysis period at both sites (Figure 4-6). Discrete TKN concentrations only exceeded the interim regulatory standard in the study reaches in one instance during the analysis period: once in April 2010 at the above Elkhead station (Figure 4-7). Notably, this exceedance took place in the month of April, when the onset of spring runoff commonly occurs (Day 2021). Discrete TN concentrations (Figure 4-7) exceeded the interim regulatory standard twice at the below Craig station (once in both 2000 and 2002) and once at the above Elkhead station (2010). Each of these exceedances occurred in either March or April during spring snowmelt events. In light of these infrequent exceedances – and especially the lack thereof for more than a decade – each riverscape scores an A with respect to nitrogen.

Table 4-11. Modeled Median Kjeldahl Nitrogen and Total Phosphorous Concentrations for Each Water Year and the Overall Period of Analysis (adapted from Day [2021])

Station	2010	2011	2012	2013	2014	2015	2016	2017	2018	2010-18
Modeled Median Kjeldahl Nitrogen concentration (mg/L)										
Yampa River above Elkhead Creek	0.44	0.39	0.37	0.35	0.39	0.39	0.36	0.37	0.37	0.38
Yampa River below Craig	0.38	0.37	0.39	0.39	0.38	0.38	0.38	0.38	0.39	0.38
Modeled Median Total Phosphorous Concentration (mg/L)										
Yampa River above Elkhead Creek	0.059	0.056	0.046	0.044	0.053	0.054	0.049	0.052	0.045	0.050
Yampa River below Craig	0.042	0.047	0.039	0.040	0.044	0.042	0.040	0.042	0.039	0.042

Note: All years are water year (October-September) rather than calendar year

Figure 4-6. Modeled Kjeldahl Nitrogen and Total Phosphorus for the Yampa River above Elkhead and below Craig Gaging Stations from 2010 – 2018 (Adapted from Day [2021])



Like nitrogen, total phosphorous (TP) is measured quarterly at both stations in the study area, and these quarterly samples were used to estimate daily TP concentrations. Estimated median annual total phosphorous (TP) was below the interim regulatory standard of 0.11 mg/L for cold water rivers and 0.17 mg/L warm water rivers for all water years over the analyzed period for both sites (Table 4-11, Figure 4-6). However, summarizing the data at the annual scale obfuscates some trends; at closer examination, estimated daily concentrations exceeded the standard fairly frequently during the spring months. Median monthly values of TP for the period analyzed exceed the cold-water regulatory standard in both April and May at the above Elkhead station (Figure 4-6). Additional information is provided by examining the modeled data at the daily scale; exceedance occurs for a number of days in March-June. For the above Elkhead station, median number of days over the period of record in which the water quality standard is exceeded are 3, 21, 29, and 10.5 days for March, April, May, and June, respectively; however, at the below Craig site, the median number of days in exceedance are 0.

Measured discrete phosphorous concentrations also exceeded the standard fairly frequently during the spring months. At the above Elkhead station, TP in discrete samples was greater than 0.11 mg/L for six individual samples: March 2012, April 2010, May 2011, May 2016, and May 2022, and December 2010 (Figure 4-7). At the below Craig station, exceedance of 0.17 mg/L occurred five times in total from 1999-2022: all during the spring snowmelt months of April (2002, 2008, 2010) and May (2003 and 2011) (Figure 4-7). Given the fairly frequent exceeded of regulatory standards during the spring and early summer months – but only the spring and early summer – at the above Elkhead site, riverscapes 17, 18, 19 and 20 earn a score of C for phosphorous; conversely, due to the lack of frequent exceedances at the below Craig site, riverscapes 22, 23, and 24 earn a B score. Combined nutrient indicator scores are provided in Table 4-12.

Figure 4-7. Measured (Discrete) Kjeldahl Nitrogen, Total Nitrogen, and Total Phosphorus Values for the Yampa River above Elkhead and Yampa River below Craig Gaging Stations

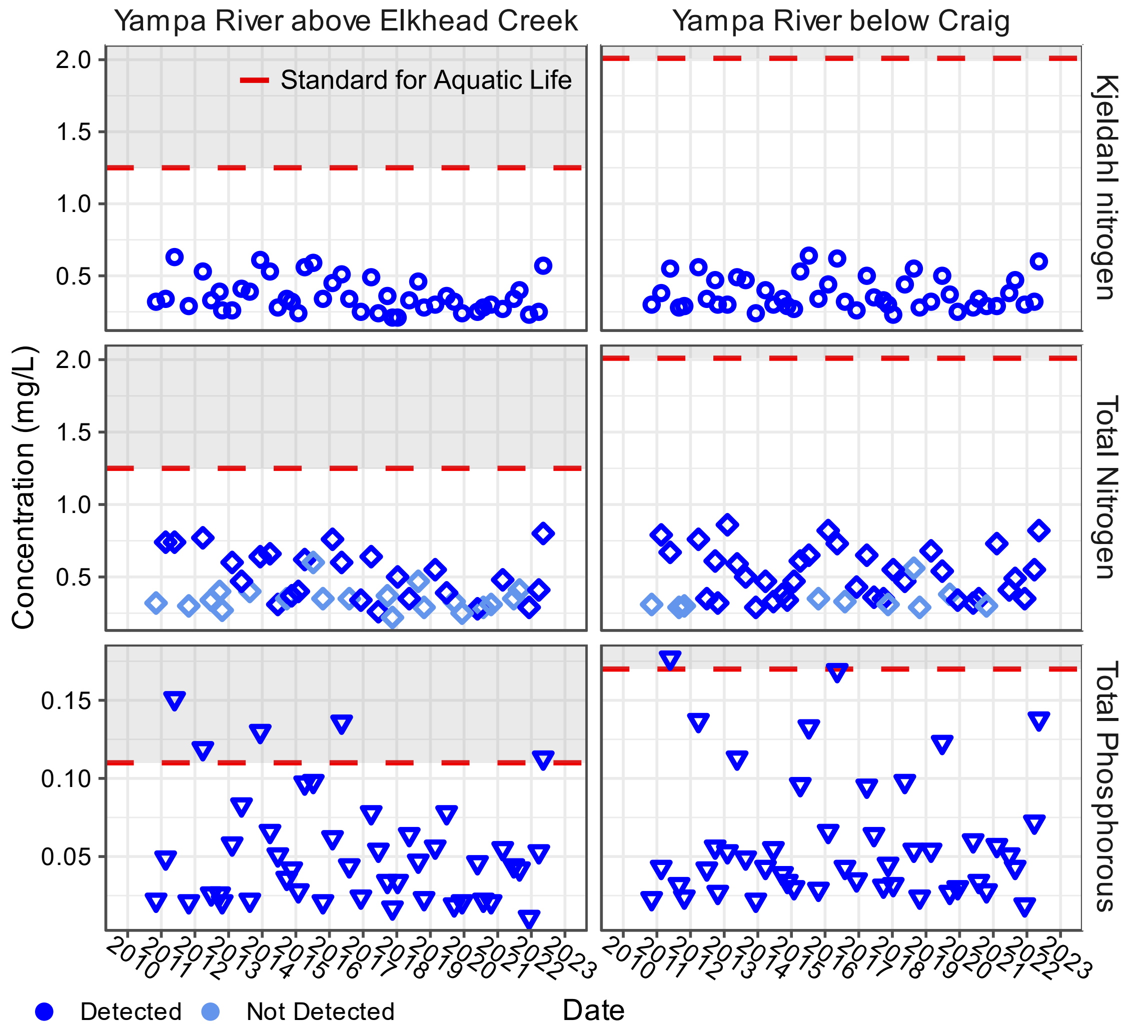


Table 4-12. Nutrients Indicator Scores by Riverscape

Riverscape	Nitrogen Score	Phosphorus Score	Nutrients Score
Riverscape 17	A	C	B
Riverscape 18	A	C	B
Riverscape 19	A	C	B
Riverscape 20	A	C	B
Riverscape 22	A	A-	A-
Riverscape 23	A	A-	A-
Riverscape 24	A	A-	A-

4.6 METALS INDICATOR

Metals generally occur at low concentrations in surface waters, and a number of them are essential nutrients to aquatic biota, but they are toxic at higher concentrations. CDPHE sets regulatory standards for most metals based on the uses identified for each stream segment (e.g., water supply, agriculture, recreation, aquatic life protection); if water quality samples frequently exceed these standards, the stream segment is placed on the State's 303(d) or M&E (monitoring and evaluation) list for that particular constituent.

4.6.1 Data Sources and Evaluation Methods

Select trace metals (total iron and manganese; dissolved cadmium, copper, lead, manganese, selenium, silver, and zinc) are measured quarterly by USGS as part of the Upper Yampa River Basin Water Quality Monitoring Program. Two locations in the Scorecard focal segment are part of this monitoring program: Yampa River Above Elkhead Creek Near Hayden, CO and Yampa River below Craig, CO. Data were downloaded from nwis.waterdata.usgs.gov. FOTY also collected two water quality samples at the Craig Intake location (riverscape 23) in 2022: one in June during high-flow conditions, and one in September during low-flow conditions.

4.6.2 Scoring Criteria

The scoring criteria outlined in Table 4-13 based on adherence to regulatory standards set by CDPHE are used to rate the metals indicator.

Table 4-13. Metals Indicator Scoring Criteria

Grade	Description
A	Chemical conditions are within ranges that are natural and appropriate for a well-functioning river in its process domain.
B	Chemical conditions are within the range of natural variability. Natural aquatic biota are minimally impaired even though background concentrations of certain metals may be elevated. Regulatory standards are not exceeded (except for metals with elevated background concentrations).
C	Chemical conditions are altered to a degree that could potentially limit natural aquatic biota. Stressors are present which create conditions that may warrant inclusion on State impaired waters lists. CDPHE Monitoring and Evaluation (M&E) listed reaches fall in this category.
D	Chemical conditions are altered to a degree that is known to be lethal or limiting to natural aquatic biota. Regulatory standards are frequently exceeded. CDPHE 303(d) listed reaches fall in this category.
F	The chemical environment is fundamentally altered. Natural biota are severely impaired. Regulatory standards have been exceeded consistently.

4.6.3 Results

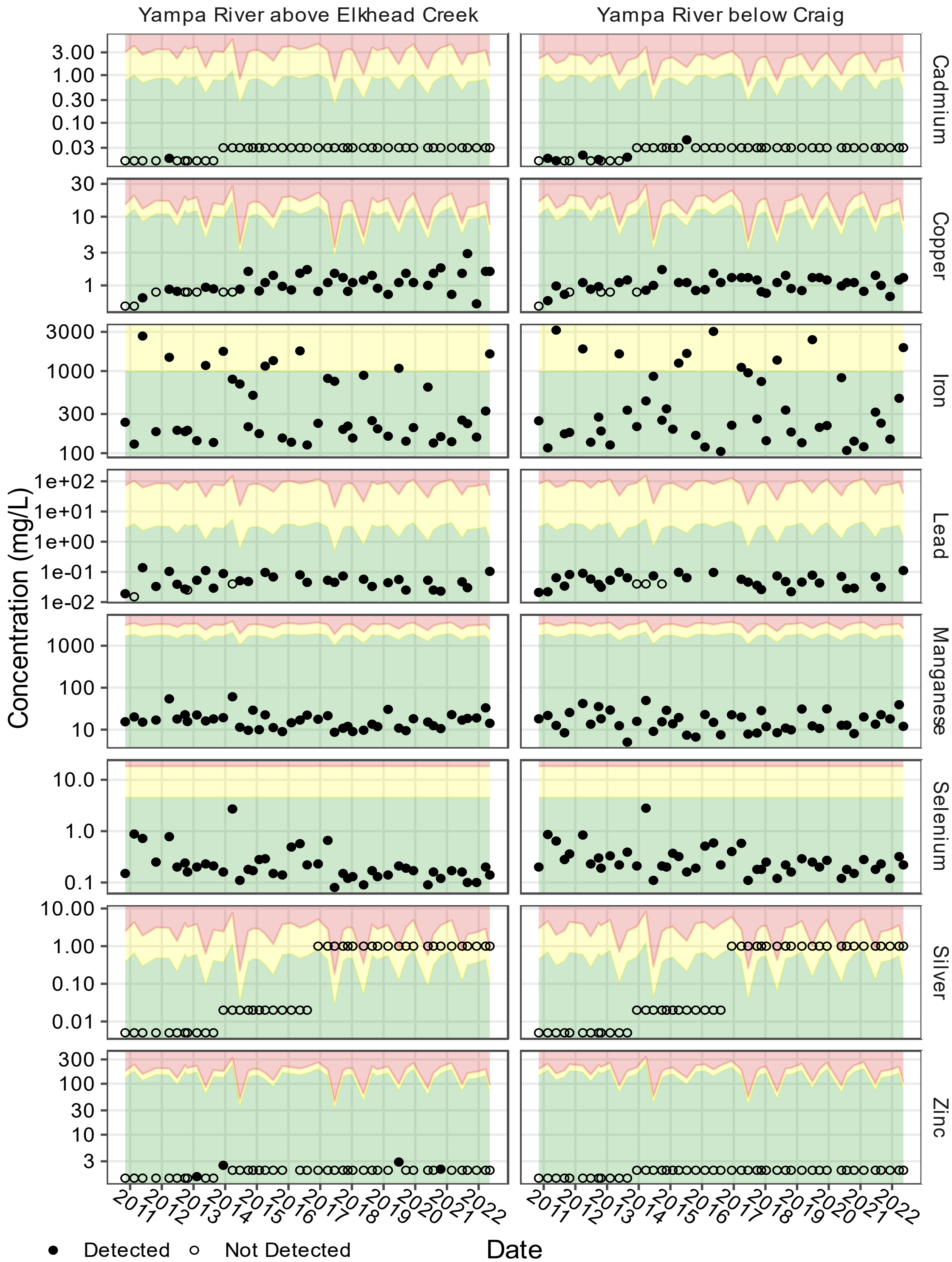
The metals indicator is evaluated through review of USGS Water Quality Monitoring Program data at the Yampa River above Elkhead Creek Near Hayden, CO and Yampa River below Craig, CO monitoring locations, where total iron, total and dissolved manganese, dissolved cadmium, dissolved copper, dissolved lead, dissolved selenium, dissolved silver, and dissolved zinc are measured quarterly. As was done with the nutrients indicator, because rivers integrate upstream inputs, data from the above Elkhead station (located in riverscape 20) are used to score riverscapes 17, 18, 19, and 20; data from the below Craig station (located in riverscape 24) are used to score the remaining riverscapes (riverscapes 22, 23, 24). A USGS analysis of metals and other water quality data for the Upper Yampa Basin for the 1979-2009 period was completed in 2012; portions of this report that contain analysis and interpretation of data for the Yampa River above Elkhead site (the below Craig site was outside the area covered) were examined for additional context (Bauch et al. 2012).

Of the metal constituents analyzed, all except iron were consistently below CDPHE regulatory standards at both monitoring locations (though the detection limit of the method used to calculate silver concentrations post-2015 precludes stating this with certainty) (Figure 4-8). In the figure, open circles indicate that concentration was below the level of the position of the point (e.g., an open circle at 1 mg/L for silver suggests that silver concentration for that sample was < 1 mg/L). Red shading indicates acute contamination standard; yellow is chronic; green is acceptable the range for aquatic life. Elevated iron levels are likely lithologically driven; the sedimentary and igneous rocks in the Yampa Basin contain iron and iron-bearing minerals in relatively high concentrations (Bauch et al. 2012). Likely because of the high natural iron content in the surrounding rocks and because of the relatively few exceedances of the regulatory standard, the CDPHE monitoring segment of the Yampa River contained within the Scorecard riverscapes is listed as M&E or 303(d) (interestingly, however, lower portions of the Yampa are 303(d) listed for iron). Overall, the relatively low concentrations of metals in the riverscapes considered is not unexpected due to the recent cessation or overall lack of activities that generally enhance in-stream concentrations of metallic species (e.g., industrial production, mining of precious metals). Every riverscape therefore scores an A for the metals indicator (Table 4-14).

Table 4-14. Metals Indicator Scores by Riverscape

Riverscape	Metals Score
Riverscape 17	A
Riverscape 18	A
Riverscape 19	A
Riverscape 20	A
Riverscape 22	A
Riverscape 23	A
Riverscape 24	A

Figure 4-8. Total (Iron) and Dissolved Metals Concentrations from Quarterly Water Sampling at the Yampa River above Elkhead Creek and Yampa River below Craig, CO Locations (2010-2022)



5.0 HABITAT CONNECTIVITY

Habitat connectivity is defined as the interaction and interconnectedness between a river segment and its surrounding landscape, including pathways for movement of biological organisms and organic matter through the riparian corridor. This category includes connectivity of both terrestrial and aquatic communities and considers both longitudinal (upstream/downstream) and lateral (channel/floodplain/upland) directions. The Yampa River Scorecard evaluates two indicators within the habitat connectivity category: **aquatic connectivity** and **terrestrial connectivity**. The final habitat connectivity score is calculated as an average of the aquatic connectivity and terrestrial connectivity indicator scores.

5.1 AQUATIC CONNECTIVITY INDICATOR

The aquatic connectivity indicator addresses the ability for aquatic organisms to migrate and disperse in both longitudinal (upstream/downstream) and lateral (between the channel and floodplain, e.g., side channels) directions. This indicator looks at presence or absence of barriers to aquatic movement.

5.1.1 Data Sources and Evaluation Methods

Data to score this indicator are collected by floating the entire focal segment of the Yampa River and identifying (and marking with GPS) any in-channel barriers to aquatic species movement. This fieldwork was completed during a 10-day field course in June 2022 coordinated in partnership with Colorado Mountain College (Appendix A). To the extent possible, observers assessed the height of the barrier or dam, and the amount of time of the year and associated flow conditions where that structure poses a barrier to aquatic species movement (e.g., only passable during spring runoff, impassable during all flow conditions, etc.).

Field floats also identify the following features that are important to aquatic species migrating laterally for spawning and cover:

- Permanently inundated side channels;
- Seasonally inundated side channels;
- Backwater areas; and
- Split flows (i.e., two narrow channels versus one wide channel).

Fieldwork is augmented by review of historical aerial imagery to reflect the complexity and evolution of the riverscapes in terms of aquatic connectivity.

5.1.2 Scoring Criteria

The scoring criteria outlined in Table 5-1 based on presence and extent of barriers to aquatic species movement are used rate the aquatic habitat connectivity indicator.

Table 5-1. Aquatic Habitat Connectivity Indicator Scoring Criteria

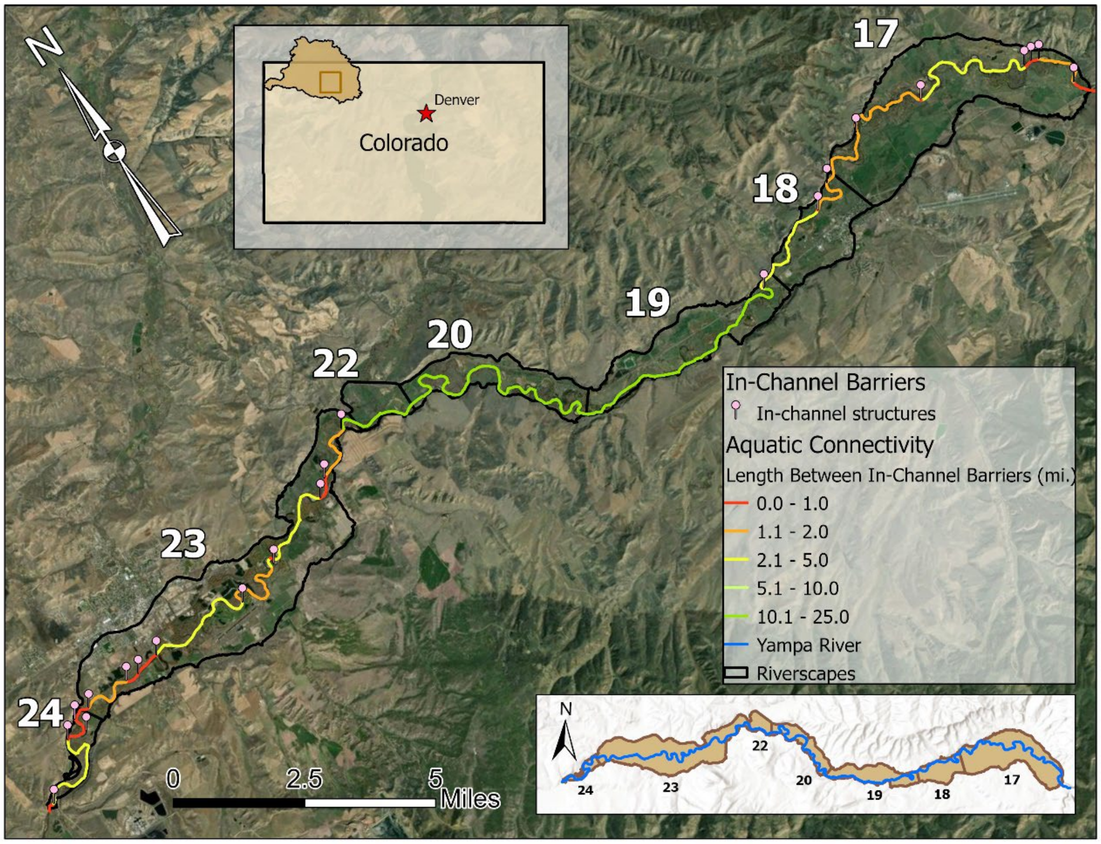
Grade	Description
A	No significant barriers exist that prevent migration or dispersal of aquatic organisms within the entire ecoregion and upstream headwaters.
B	Impermeable migration/dispersal barriers are at least 10 miles apart and/or there are minor migration/dispersal impediments on the reach or adjacent reaches. Mild loss of side channel and/or backwater area access may impact spawning and cover for certain species.
C	Impermeable migration/dispersal barriers are approximately 5 miles apart and/or there are multiple migration/dispersal impediments on the reach or adjacent reaches. Moderate loss of side channel and/or backwater area access may impact spawning and cover for certain species.
D	Impermeable migration/dispersal barriers are approximately 2 miles apart and/or migration/dispersal is severely impeded on the reach or adjacent reaches. Substantial loss of side channel and/or backwater area access may impact spawning and cover for certain species.
F	The reach is effectively isolated. Impermeable migration/dispersal barriers are approximately 1 mile apart or less and/or migration/dispersal is completely impeded on the reach or adjacent reaches. Access to side channel and/or backwater areas for spawning and cover is unavailable.

5.1.3 Results

The results of aquatic connectivity scoring are composed of two parts that together yield an overall score for this indicator: barriers to longitudinal connectivity (e.g., dams) and pathways for lateral connectivity (e.g., side channels).

In contrast with other rivers of the Colorado River Basin – and what makes the Yampa such a cherished treasure – in-channel barriers to upstream-downstream movement are minimal. Those that do exist generally take the form of "push-up" dams constructed to coerce water into a diversion structure or channel crossings such as bridges, but they are relatively dispersed throughout the study reaches and are generally clustered in the upper and lower riverscapes (Figure 5-1); the middle riverscapes (19, 20, and 22) notably lack such structures (Figure 5-1). The lack of in-channel barriers in riverscape 20 is not surprising given that the river flows within the boundaries of Yampa River State Wildlife Area for nearly the entirety; however, the scarcity of structures in riverscapes 19 and 22 is relatively surprising due to the substantial agricultural activity in these reaches. This condition may be attributed to the use of pumps for irrigation rather than gravity-fed ditches (two of the largest diversions in riverscape 19 are pump-driven, the Yoast Pumping Plant and the Frentress Ditch and Pumping Plant), diminishing the need for large push-up structures, as well as the preponderance of smaller livestock watering diversions in the middle riverscapes rather than the larger crop irrigation diversions seen elsewhere. Indeed, in-channel barriers are found with a relatively greater frequency in riverscapes 17, 18, 23, and 24, where agricultural activity is more prevalent. Several road crossings also exist in these upper and lower riverscapes that are not present in the middle reaches; the resulting relatively low scores regarding in-channel structures are therefore relatively unsurprising (Table 5-2).

Figure 5-1. In-Channel Barriers to Longitudinal Movement as Observed in the Field



Pathways for lateral movement (e.g., side channels) are commonly found along the Yampa throughout the study area. The presence of such features enables aquatic organism to extricate themselves from the higher energy of the main channel into relatively sheltered and quiescent waters. Lateral connectivity pathways are thus important for spawning and rearing of several species of fish, as well as for other organisms that may move frequently between the main river channel and the neighboring floodplain (e.g., beaver). Lateral pathways scores were determined by (1) calculating the number of such features observed in the field and on imagery per river mile, and then (2) evaluating that number relative to what may be expected of a natural river in its process domain using the following rubric, which dovetails with the scoring criteria laid out in Section 5.1.2: No loss of side channel access (>4/mile); mild loss of side channel access (<4/mile); moderate loss of side channel access (<3/mile); substantial loss of side channel access (<2/mile); and full loss of side channel access (<1/mile). Lateral pathways were most frequent and widespread in riverscapes 17, 19, 20, and 23 (Figure 5-2); these riverscapes therefore earned the highest scores (Table 5-2). Inspection of aerial imagery suggest that high scores may be a function of the presence of substantial portions of intact riparian forest along these riverscapes, emphasizing the benefits of preserving such floodplain ecosystems for the river. A notably low score for the presence of lateral pathways occurred in riverscape 24, likely due to the fact that the river here is bounded by a large interstate highway and a railroad.

Figure 5-2. Locations of Pathways for Lateral Movement as Observed in the Field

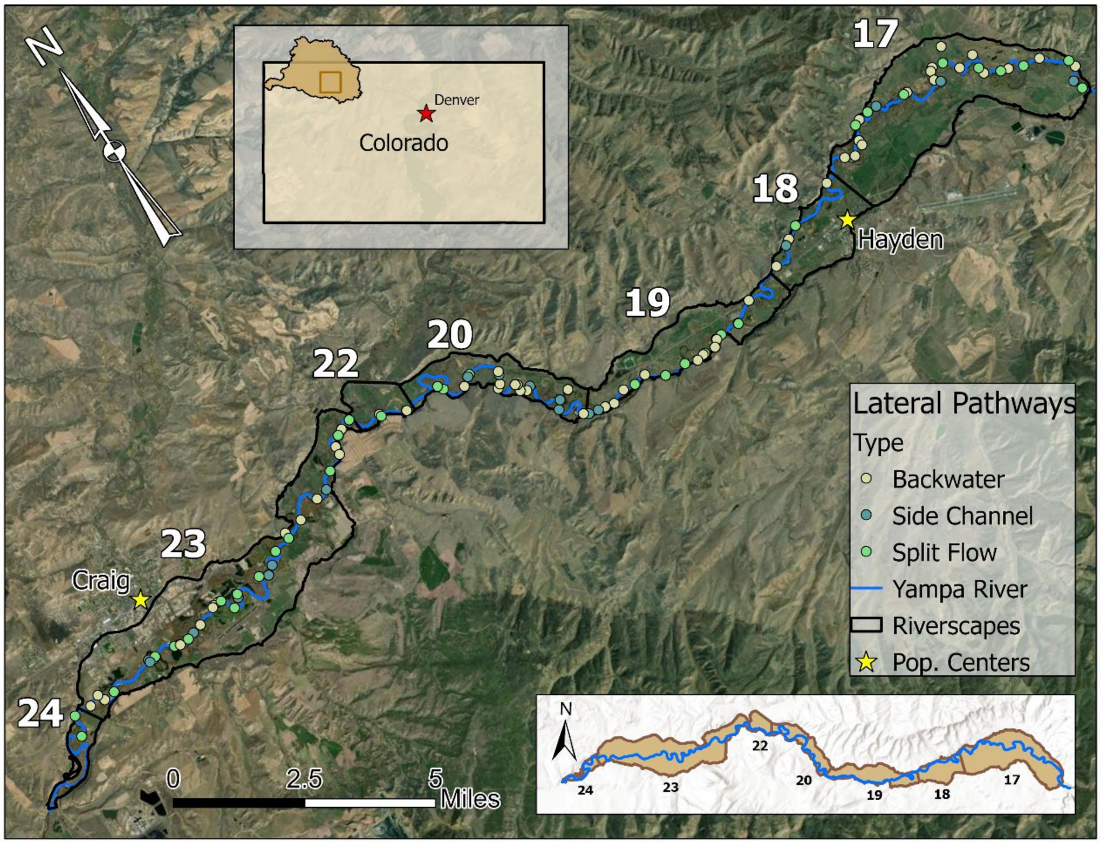


Table 5-2. Aquatic Connectivity Indicator Scores by Riverscape

Riverscape	Barriers Score	Lateral Pathways Score	Aquatic Connectivity Score
Riverscape 17	C-	A	B-
Riverscape 18	C	B	B-
Riverscape 19	A	A	A
Riverscape 20	A	A	A
Riverscape 22	A	B	A-
Riverscape 23	D	A	C
Riverscape 24	D	D	D

5.2 TERRESTRIAL CONNECTIVITY INDICATOR

The terrestrial connectivity indicator addresses the ability of terrestrial organisms to move both longitudinally (upstream/downstream) and laterally (between the channel and riparian zone, between riparian zone and upland areas). This indicator considers habitat fragmentation, including barriers created by roads, railroads, trails, bridges, fences, etc.

5.2.1 Data Sources and Evaluation Methods

The Scorecard relies on floodplain fragmentation metric results from the Yampa IWMP remote assessment that was conducted as part of the riparian condition evaluation (Yampa IWMP 2021). For context, the Yampa IWMP remote assessment evaluated riparian condition across the basin using the Riparian Condition Assessment Tool (RCAT) developed by Utah State University (MacFarlane et al. 2018). RCAT provides a holistic proxy measure of riparian condition by assessing and integrating three key metrics of riparian functions: (1) riparian vegetation departure from historical conditions, (2) land use intensity within valley bottoms, and (3) floodplain fragmentation by infrastructure (roads, railroads, levees, etc.). The floodplain fragmentation metric calculates the proportion of accessible versus inaccessible floodplain within a reach due to roads, railroads, levees, or other infrastructure. Scores range from one (fully accessible) to zero (inaccessible). The floodplain fragmentation statistic calculated for each riverscape (encompassing the lateral extent of the entire valley bottom) is coupled with review of aerial imagery to rate the terrestrial connectivity indicator.

5.2.2 Scoring Criteria

The terrestrial connectivity indicator scoring criteria outlined in Table 5-3 are based on floodplain fragmentation and severity and proximity of migration barriers to terrestrial species movement.

Table 5-3. Terrestrial Connectivity Indicator Scoring Criteria

Grade	Description
A	Negligible fragmentation of the floodplain by infrastructure and development, with a floodplain fragmentation score of > 91%. No significant barriers to migration or dispersal of terrestrial organisms.
B	Minor fragmentation of the floodplain by infrastructure and development, with a floodplain fragmentation score between 71-90%. Impermeable barriers affect a minor portion of surrounding habitat, but permeable barriers such as gravel roads, minor berms, ditches, or barbed wire fences may be present.
C	Moderate fragmentation of the floodplain by infrastructure and development, with a floodplain fragmentation score between 41-70%. Impermeable barriers affect a moderate portion of surrounding habitat, and semi-permeable barriers such as two-lane paved roads, rail lines, or widely scattered residential development may be present.
D	Significant fragmentation of the floodplain by infrastructure and development, with a floodplain fragmentation score between 21-40%. Impermeable barriers and/or permeable barriers affect a substantial portion of surrounding habitat.
F	Severe fragmentation of the floodplain by infrastructure and development, with a floodplain fragmentation score of < 20%. Impermeable barriers and/or permeable barriers affect almost all of the surrounding habitat.

5.2.3 Results

This indicator is scored through review of IWMP remote assessment results and confirmation from aerial imagery. Briefly, the Yampa River Remote Assessment delineated the floodplain using a variety of data sources and then overlayed various infrastructure layers (roads, levees, railroads, etc.) to calculate the fraction of the floodplain that was isolated by that infrastructure. See Section 6.2.1.1.3 in the Yampa River Remote Assessment Data Synthesis Report for further details on the methodology (Yampa IWMP 2021).

Floodplain fragmentation is, unsurprisingly, relatively highest – though still only moderate – in those riverscapes that contain the major population centers of Hayden and Craig (riverscapes 19 and 23, respectively), where infrastructure and development isolate substantial portions of the floodplain landscape (Table 5-4, Figure 5-3). Minor fragmentation occurs in riverscapes 17, 18, and 20, generally resulting from the railroad and surface roads (e.g., US-40); permeable barriers such as agricultural infrastructure (e.g., fencing, gravel roads) are also present. Negligible fragmentation is found in riverscapes 22 and 24, likely because of the relatively high degree of natural confinement that limits development and fragmentation "potential" (especially for riverscape 24) and potentially because of statistical idiosyncrasies wherein the relatively small areas of riverscapes 22 and 24 – the smallest in the Middle Yampa segment – lowers the probability of substantial fractionation (Table 5-4, Figure 5-3). The confluence with the tributary Elkhead Creek that occurs in riverscape 22 likely also results in a low degree of fractionation due to the orientation of the confluence (orthogonal) relative to infrastructure. Scores for the terrestrial connectivity indicator are presented in Table 5-5.

Table 5-4. Floodplain Fragmentation Percent by Riverscape

Riverscape	Floodplain Fragmentation
17	77%
18	80%
19	67%
20	85%
22	94%
23	65%
24	96%

* Adapted from the Yampa River Remote Assessment Data Synthesis Report (Yampa IWMP 2021); higher percentages correspond to minimal fragmentation and lower percentages correspond to greater fragmentation of the landscape.

Figure 5-3. Floodplain Fragmentation (Representing Terrestrial Connectivity) by Riverscape

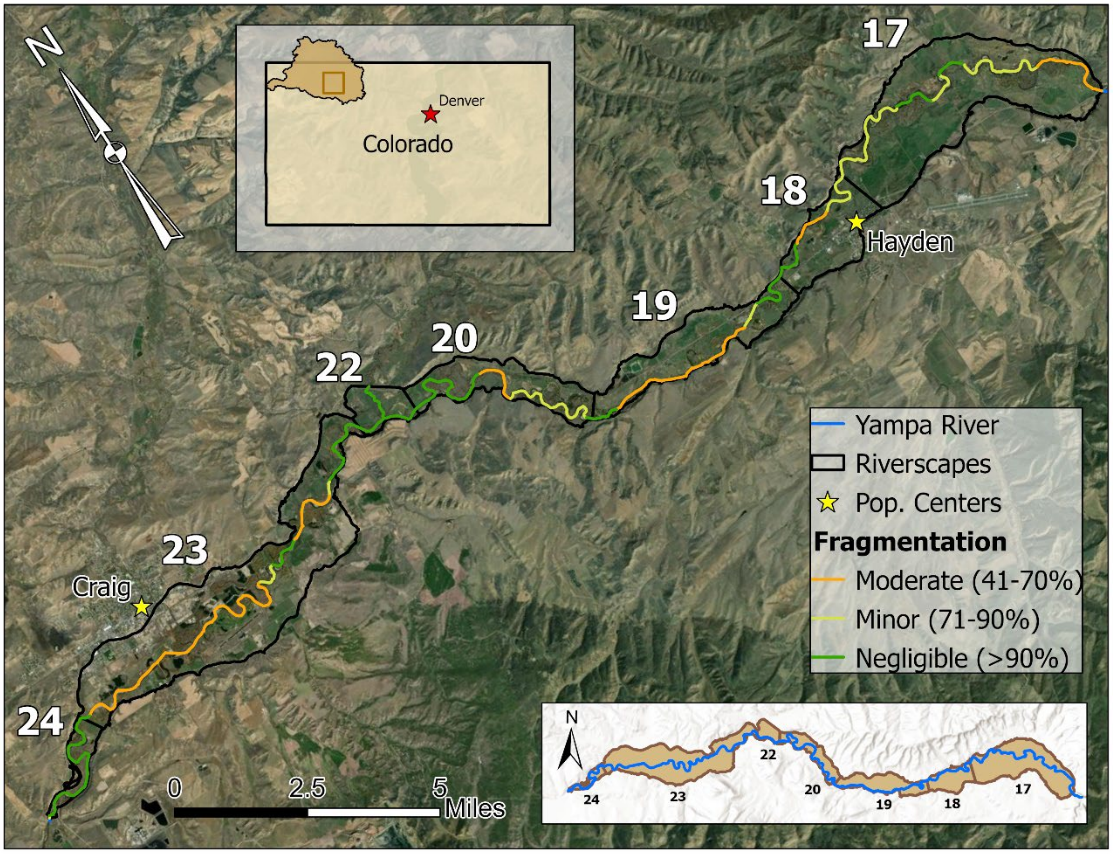


Table 5-5. Terrestrial Connectivity Indicator Scores by Riverscape

Riverscape	Terrestrial Connectivity Score
Riverscape 17	B
Riverscape 18	B
Riverscape 19	C
Riverscape 20	B
Riverscape 22	A
Riverscape 23	C
Riverscape 24	A

6.0 RIVERSCAPE CONNECTIVITY

Riverscape connectivity is defined as the degree to which water can access and hydrate the surrounding riverscape (channel and floodplain). In particular, riverscape connectivity reflects the ability of the valley bottom to be actively and routinely engaged by fluvial processes. Connectivity varies naturally based on geology, topography, and hydrology. It also reflects impediments due to hydromodifications, channel modifications (e.g., enlargement, entrenchment, channelization/ stabilization), and/or anthropogenic land uses within the floodplain (e.g., levees, drainage ditches, development, fill), which limit hydrogeomorphic processes, dynamism of channel/floodplain interaction, and biological interactions between the channel and its floodplain. The Yampa River Scorecard evaluates riverscape connectivity using a single indicator referred to as **riverscape connectivity**.

6.1 RIVERSCAPE CONNECTIVITY

Riverscape connectivity for the Scorecard project is defined as the ratio of the active floodplain to the maximum possible floodplain extent, as was done for the Yampa IWMP remote assessment. The Yampa IWMP remotely evaluated a Floodplain Connectivity indicator across the entire basin, described as the ratio of the accessible extent of the active floodplain to the maximum potential accessible floodplain (Yampa IWMP 2021). The floodplain connectivity ratio is a proxy measure of the extent and frequency with which flows interact with the channel and adjacent floodplain. This interaction is critical for creating and maintaining a healthy stream corridor by helping establish and maintain riparian vegetation throughout the floodplain, which in turn extends inundation residence times by attenuating and slowing flows through the system.

For the Yampa IWMP remote assessment, floodplain connectivity was assessed across the entire basin, and reassessed using higher resolution data in a portion of the Scorecard focal segment, to characterize the capacity of water to inundate and activate the adjacent riparian corridor. The higher resolution data used for a section of the focal segment allow for better identifying and mapping fluvial features and more accurately delineating floodplain extents. It is important to note that a critical component of accurate floodplain and geomorphic delineations is field verification. While the remote assessment provides a good foundation, the Scorecard effort provides ground-truthing, field verification, and refinement of those results to the extent possible (described more in Section 6.1.5).

The active floodplain is defined as the extent to which flows can access the land adjacent to the river over frequent to moderate recurrence intervals. The active floodplain delineates the areas where inundation duration and frequency can maintain riparian vegetation and active fluvial processes. To determine the area occupied by active floodplain via remote sensing, two lines of evidence were used: (1) floodplain fragmentation by development and transportation infrastructure, which have disconnected low-lying areas from the active floodplain, and (2) topographic datasets to identify low-lying areas that have the potential to be inundated at frequent to moderate recurrence intervals. Integration of the floodplain fragmentation and the potentially active floodplain layers were used to delineate the active floodplain. The active floodplain is defined as land that is within the potentially active floodplain that has not been disconnected by development or transportation networks. Figure 6-1 shows some of the steps taken to determine the floodplain connectivity ratios for the Yampa IWMP remote assessment (Yampa IWMP 2021).

Figure 6-1. Yampa IWMP Remote Assessment Floodplain Connectivity Metrics Example

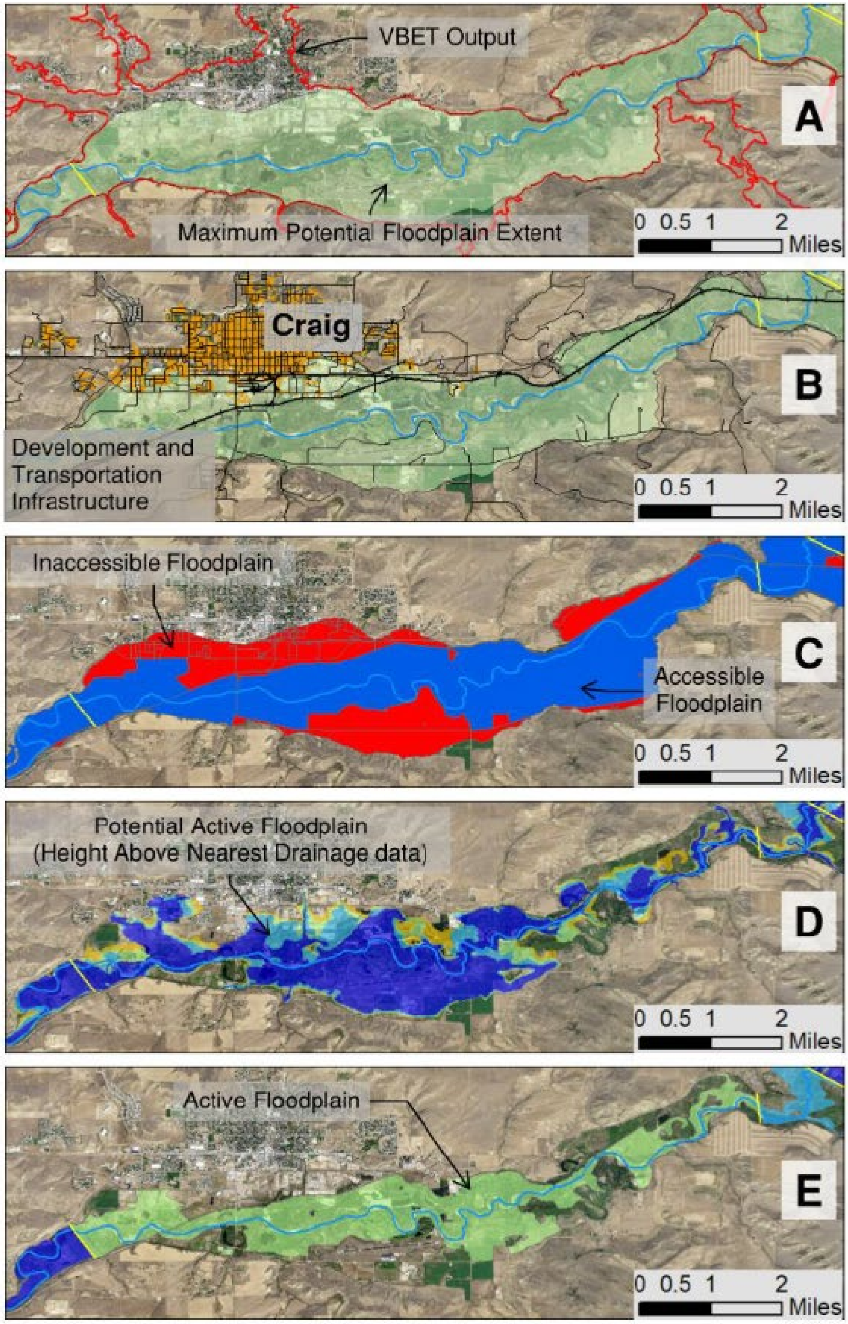


Figure 6-1. Example floodplain connectivity metrics for Riverscape 23 (see Figure 2-4 for context). A) VBET outputs and manually modified valley bottom representing the maximum potential floodplain extent. B) Development and transportation infrastructure overlain on valley bottom polygon. C) Floodplain fragmentation by development and transportation network. D) Potential active floodplain based on Height Above Nearest Drainage. E) Active floodplain.

6.1.1 Data Sources and Evaluation Methods

The Scorecard uses the results of the Yampa IWMP remote assessment floodplain connectivity evaluation to score the riverscape extent indicator. However, the remote assessment did not include a field verification component. For the Scorecard, the floodplain connectivity ratios for the seven relevant riverscapes in the focal segment were ground-truthed to the extent possible, particularly in unconfined reaches where the remote assessment may have overestimated the maximum potential floodplain extent, through site visits in areas with landowner access permissions. Select sites were visited for field verification by a geomorphologist, hydrologist, and watershed scientist team in September 2022. Where discrepancies were identified, the Scorecard provides explicit rationale and alters the IWMP evaluation as necessary based on the field verification exercise and uses an updated score for evaluation per the scoring criteria described in Section 6.1.3.

6.1.2 Scoring Criteria

The scoring criteria outlined in Table 6-1 based on Yampa IWMP remote assessment floodplain connectivity ratios are used rate the riverscape extent indicator.

Table 6-1. Riverscape Extent Scoring Criteria

Grade	Description
A	Natural pattern of floodplain activation over frequent to moderate recurrence intervals, with a floodplain connectivity ratio of > 90%.
B	Majority of riverscape extent is available for activation over frequent to moderate recurrence intervals, with a floodplain connectivity ratio of 75-90%.
C	Moderate amount of riverscape extent is available for activation over frequent to moderate recurrence intervals, with a floodplain connectivity ratio of 50-74%.
D	Small amount of riverscape extent is available for activation over frequent to moderate recurrence intervals, with a floodplain connectivity ratio of 25-49%.
F	Riverscape activation over frequent to moderate recurrence intervals is extremely limited, with a floodplain connectivity ratio of < 25%.

6.1.3 Results

This indicator is scored using a combination of review of IWMP remote assessment results and data collected during site visits with Scorecard partners. Adjustments to active floodplain polygons generated by the IWMP were edited using ground truthing and aerial photograph inspection for riverscapes 18, 19, 22, 23, and 24. Additionally, in place of the IWMP active floodplain delineation, fluvial hazard zone mapping of the active stream corridor (using high-resolution data) was used to replace the IWMP active floodplain delineation (using moderate-resolution data) for riverscape 17 (Jagt et al. 2022). Maximum floodplain extents are the same as those delineated in the IWMP report. Additionally, the floodplain connectivity multipliers determined by the IWMP assessment by comparison of floodplain mapping results in areas with high resolution elevation (1-m) data to those in areas with moderate resolution elevation (10-m) data were used here as well.

The highest floodplain connectivity scores are found in riverscapes 22 and 24, where 95% and 85% of the floodplain, respectively, is readily accessible by relatively frequent flows (Table 6-2, Table 6-3, and Figure 6-2). Both are somewhat surprising given the relatively poor scores in other indicators for these riverscapes. The high score for riverscape 24 likely arises from the natural confinement of the river in this stretch; opportunities for development or other human actions that render portions of the floodplain inaccessible are typically limited in a confined valley. The high score for riverscape 22 is perhaps primarily a function of the confluence with Elkhead Creek, which at high stage appears to access much of the northern portion of the floodplain through the riverscape. The high degree of connectivity may additionally be a function of the comparatively smaller size of riverscape 22 and natural barriers (e.g., Elkhead confluence) that inhibit extensive infrastructure development on the floodplain.

The next highest grade is for riverscape 20 (Table 6-3 and Figure 6-2). The score for riverscape 20 is unsurprising given the high grades in many of the other indicators for this riverscape, suggestive a well-connected river.

The lowest grades received are for riverscapes 17, 18, 19, and 23 (Table 6-3 and Figure 6-2). Again, the inclusion of riverscape 17 here is rather surprising; however, it likely stems from the unconfined character of this reach – one of only two truly unconfined riverscapes in the Middle Yampa segment (Table 6-2) – and the high degree of development (agriculture, transportation, etc.) in these areas. US Route 40 and the Union Pacific railroad, for example, cut large portions of the river off from its historically accessible floodplain in all three riverscapes. Further development, such as the campground in riverscape 19, additionally isolates the river from the floodplain. Of these four reaches with moderate or small amounts of connection, the two absolute lowest – 18 and 23 – are those where the largest population centers (Hayden and Craig, respectively) in the study segment are located.

Table 6-2. Confinement and Floodplain Connectivity Percentages by Riverscape

River-scape	Confinement	Max. Potential Floodplain (mi^2)	Active Floodplain IWMP (mi^2)	Active Floodplain YRSP (mi^2)	Floodplain Connectivity (%)	Multi-plier	Adj. Floodplain Connectivity (%)
17	Unconfined	7.9	3.01	3.80	0.48	1.3	0.62
18	P. Confined	2.03	1.04	0.77	0.38	1.3	0.49
19	P. Confined	3	1.33	1.49	0.50	1.3	0.64
20	P. Confined	2.42	1.36	1.65	0.68	1.3	0.89
22	P. Confined	0.85	0.41	0.62	0.73	1.3	0.95
23	Unconfined	10.43	4.18	4.35	0.42	1.3	0.54
24	Confined	0.64	0.54	0.54	0.85	1	0.85

Figure 6-2. Floodplain Connectivity Scores for the Middle Yampa River Segment

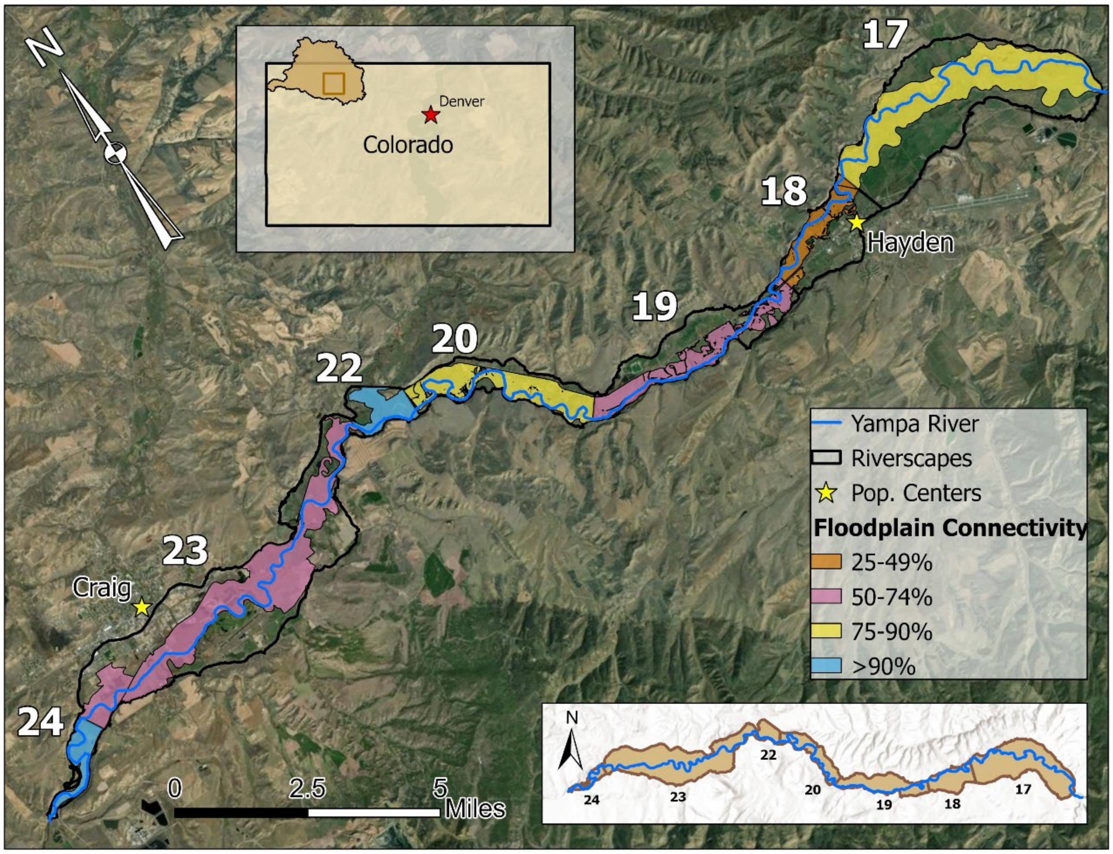


Table 6-3. Riverscape Connectivity Indicator Scores by Riverscape

Riverscape	Riverscape Connectivity Score
Riverscape 17	C
Riverscape 18	D
Riverscape 19	C
Riverscape 20	B
Riverscape 22	A
Riverscape 23	C
Riverscape 24	A

7.0 RIPARIAN CONDITION

Riparian areas, or lands that occur along and are influenced by watercourses, are a critical part of a healthy and resilient stream ecosystem, providing physical roughness that slows water velocities and mitigates the impacts of flood flows; bank stability through root system cohesiveness; habitat for a diversity of riparian plants, animals, and microbes; water quality improvement; shade for the stream corridor to maintain a healthy thermal regime; large wood to stream channels, which creates beneficial habitat complexity; organic matter to the water column; and off-channel habitats like backwaters, wetlands, and side channels that act as refugia for fish and other aquatic species. Well-established and connected riparian areas also link stream corridor and upland ecological processes. Riparian condition is defined as the degree to which riparian areas support river health and critical functions. The Yampa River Scorecard evaluates two indicators within the riparian condition category: **vegetation structure and complexity** and **invasive species**. The final riparian condition score is calculated as 90% vegetation structure and complexity indicator score and 10% invasive species indicator score.

7.1 VEGETATION STRUCTURE AND COMPLEXITY INDICATOR

The vegetation structure and complexity indicator describes riparian vegetation and its ability to support characteristic riparian functions. Healthy riparian zones are characterized by a high level of vertical and horizontal complexity, including a mosaic of habitat types and multiple vegetation layers. Included in these considerations are structure, height, cover, species diversity, complexity, age, and patchiness/interspersion of riparian vegetation. The character and complexity of riparian vegetation are primarily driven by above ground saturation and the associated disturbance caused by seasonal flooding, alluvial groundwater, and erosional and depositional changes that create bars and distribute overbank fine sediment. Complex riparian corridors in turn influence a spectrum of physical functions in the river ecosystem while providing critical wildlife habitat.

Riparian condition is evaluated within a limited portion of the maximum potential floodplain as defined in the riverscape connectivity category. In particular, it is evaluated out to a maximum of 100 meters from each channel bank. The maximum potential floodplain – and therefore potential extent of riparian vegetation – is typically considerably wider than 200 meters on the Yampa River, particularly in the Scorecard focal segment. The limited scope of the riparian condition category represents a compromise between data acquisition and available resources. The condition and extent of riparian vegetation is evaluated near the channel where it exerts the greatest control on river health, but the condition of riparian vegetation in the wider riverscape is not assessed. Future assessments will seek to expand the breadth of riparian vegetation mapping within the maximum potential floodplain in order to chart riverscape-scale changes in land cover and land use.

7.1.1 Data Sources and Evaluation Methods

Vegetation structure and complexity are evaluated using the remote polygon methodology applied in the City of Steamboat Springs SMP's river health assessment (City of Steamboat Springs 2018), with the lateral extent of the riparian zone defined as the edge of the natural floodplain or 100 meters from each river bank (200 meters total terrestrial width), whichever is narrower. This multi-step approach entails the following steps:

(1) Create and classify cover type polygons within the riparian zone (e.g., cottonwood forest, agricultural field, wetland, bare ground, residential development, etc.);
(2) conduct initial desktop grading on polygons created in step 1;
(3) field verify and refine initial polygons, particularly for polygons with natural-looking riparian vegetation;
(4) perform a calibrated grading based on information from field verification step 3;
(5) grade each cover type polygon based on Table 13, below; and
(6) calculate an area-weighted average of all polygon scores within each riverscape to produce a single vegetation structure and complexity indicator score for each riverscape.

More details regarding the methodology for this approach are provided in Appendix B.

7.1.2 Scoring Criteria

The scoring criteria outlined in Table 7-1 based on the ability of the riparian corridor to support river health functional attributes are used to rate the vegetation structure and complexity indicator.

Table 7-1. Vegetation Structure and Complexity Indicator Scoring Criteria

Grade	Description
A	Native riparian conditions exist that appear natural and appropriate for the Yampa River. Woody vegetation is present and commonly dominant, but patches and ribbons of meadow are typical. Vegetation is characteristically patchy, with strong interspersion of patches and overall good vertical structure driven by connection to the river. No evident effects of stressors – many stressors ameliorated by frequent flooding. Examples include cottonwood forest on well-connected surfaces such as vegetated point bars; young, characteristically willow-dominated, vegetation on recently formed surfaces; low, in-channel benches protected from human manipulation, typically scrub-shrub. Full support of river health.
B	Riparian habitat resembles native conditions but with detectable changes or mild, evident stressors. Vegetation appears self-sustaining and requiring little or no maintenance to preserve characteristic structural diversity. Habitat maintains a high degree of patchiness and interspersion, with little homogenization or loss of vertical structure. Small habitat patches can be relatively homogenous but contribute to the local mosaic of habitats. Common examples include river-connected cottonwood canopy and subcanopy forest with impacts such as grazing and primitive roadways. Minor reduction in the support of river health attributes.
C	Vegetated but with substantial departure from native conditions. Most commonly, alterations result in a loss of structural complexity, and/or homogenization of vertical structure, patchiness, and/or interspersion. Examples include cleared pastures that contain scattered trees and shrubs; fallow floodplain hayfields and cottonwood forests with substantial understory alteration; and palustrine emergent wetlands associated with ditches and sloughs. Riparian condition contributes to the degradation of one or more river health processes.
D	Dramatic loss of structural complexity, and/or homogenization of vertical structure, patchiness, and interspersion. Habitat commonly isolated from the river.

	Bare ground or impervious surfaces commonly makes up a significant portion of land cover. Vegetation tends to be very disturbed or actively cultivated. Examples include actively cultivated hay fields, old gravel mines, primitive roadways, and golf courses. Riparian land use contributes to river dysfunction.
F	Riparian area is developed or wholly converted with predominantly bare ground, impervious surfaces, or otherwise lacking in vegetation as a result of land use and management actions. Riparian habitat function is essentially extinguished, and land use contributes substantially to river dysfunction.

7.1.3 Results

The remote polygon desktop exercise with field verification was completed in fall 2021 in conjunction with the Yampa IWMP, and has been refined and incorporated into the Scorecard effort. Refer to Appendix B for a technical memorandum describing methods and results in more detail. A summary of results by riverscape is provided below.

The riparian zone for the middle Yampa River segment evaluated in this iteration of the Scorecard was divided into 858 polygons based first on land cover and then land use. Of the 11 cover types designated, herbaceous cover was by far the most common, accounting for more than 1,000 acres. Herbaceous areas were mostly hayfield and pasture lands. Subcanopy forest, cottonwood forest, and scrub-shrub were the three next most common cover types, which clearly illustrates the rural nature of the landscape. The cover types with the best mean condition were those in closest association with the river, including vegetated bars and scrub-shrub habitats. These areas are continually disturbed by natural processes and recover rapidly, so in most cases signs of human disturbance are quickly erased. Cottonwood and subcanopy forests are next in terms of condition, and excellent examples of both land cover types still exist on features shielded from intensive human use. Not surprisingly, developed polygons were assigned the lowest scores.

Following the pattern in land cover, ranchland and agricultural land uses are the most prevalent land uses in the middle Yampa River segment. It should be noted that there is little distinction between these two land uses, and they often overlap spatially or temporally. The agricultural land use implies that the polygon is under active cultivation, usually for hay. It is acknowledged that fields are continually taken in and out of production, and it is not always possible to determine whether and area is being actively hayed or simply has abundant herbaceous cover. With ranchlands encompassing several different land cover types, grades have a wide range (between A and D-), but it is interesting to note that many excellent examples of riparian habitat are held on ranchlands and the average grade for these habitats is a B.

Riparian condition scores based on land cover and land use were weighted by area to compute an overall riparian condition score for each of the seven riverscapes in the middle Yampa River Scorecard segment. Examples of the fine-scale riparian mapping that was completed for this assessment are provided in Appendix B, and final weighted averages by riverscape are shown in Table 7-2.

Table 7-2. Vegetation Structure and Complexity Scores by Riverscape

Riverscape	Riparian Condition Score
Riverscape 17	B-
Riverscape 18	C+
Riverscape 19	B-
Riverscape 20	B-
Riverscape 22	B-
Riverscape 23	C+
Riverscape 24	C

7.2 INVASIVE PLANT SPECIES INDICATOR

The invasive species indicator provides a measure of the presence and relative proportion of several invasive plant species that are common in the Yampa valley, including leafy spurge, Russian olive, and tamarisk.

Leafy spurge is a Colorado List B noxious weed species. It is a deep-rooted perennial that spreads explosively by seed and has extensive, creeping roots. Leafy spurge is adapted to a wide range of habitats and is very competitive with other plant species, crowding out nearly all other vegetation when it becomes established in rangeland, pasture, and riparian sites. Its white, milky sap is extremely toxic to cattle and horses, and damaging to sensitive human skin and eyes. The Yampa River Leafy Spurge Project (YRLSP) has been working to map and manage the infestation of leafy spurge in riparian areas in the valley since 2015.

Russian olive, another Colorado List B species, is a perennial tree or shrub that reproduces by seed or root suckers. Once thought to be a beneficial windbreak tree, Russian olive is detrimental to riparian zones because it outcompetes native plants, interferes with natural plant succession and nutrient cycling, and disadvantages several native animal species relative to native vegetation.

Tamarisk, or saltcedar, is also a Colorado List B noxious weed. It was introduced for ornamental purposes and streambank stabilization but is now widespread in the US and crowds out native stands of riparian and wetland vegetation. Tamarisk increases the salinity of surface soils, rendering them inhospitable to native plant species.

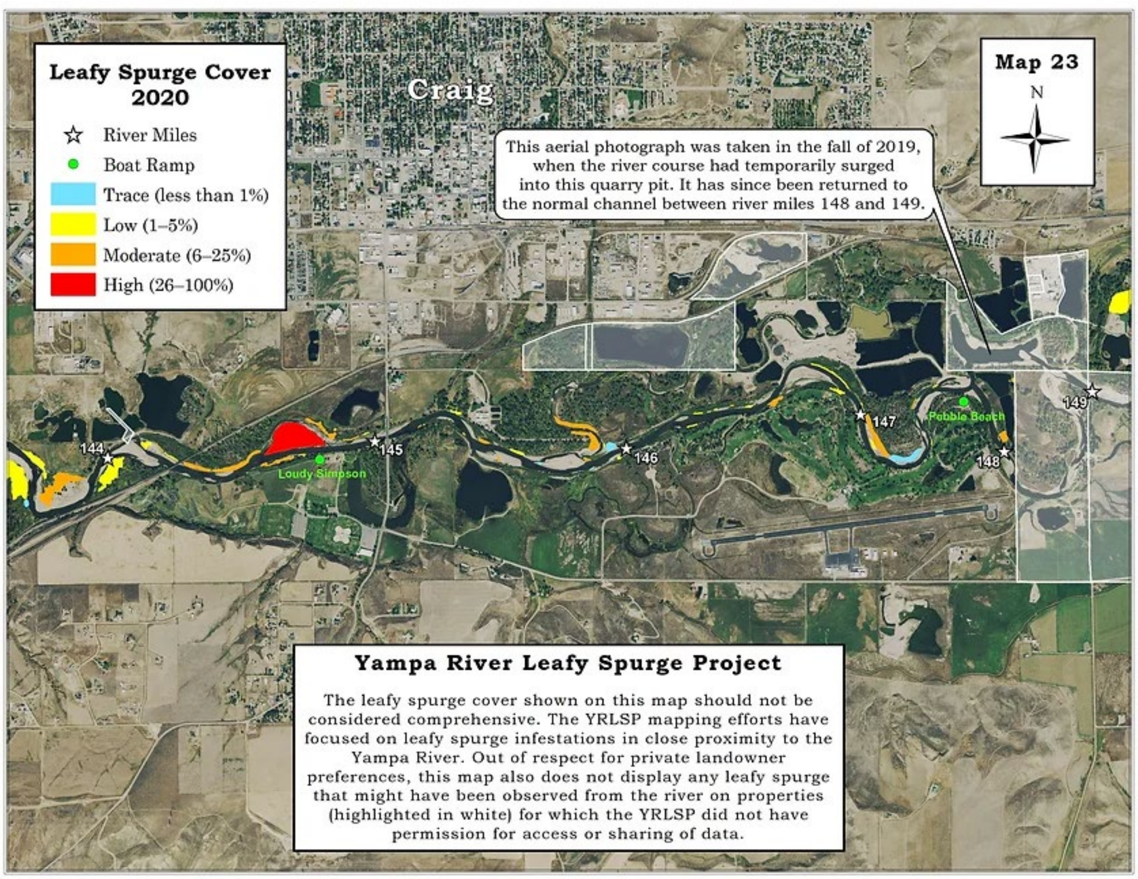
7.2.1 Data Sources and Evaluation Methods

The Yampa River Leafy Spurge Project (YRLSP) conducted field mapping of leafy spurge along the Yampa River from Hayden to Cross Mountain in 2019-2021. This field data was used by a University of Wyoming graduate student to build a remote sensing model of leafy spurge infestation in the Yampa Valley. A presentation describing this project and explaining modeling results is available at (https://www.yampariverleafyspurgeproject.com/chloemattilio) on the YRLSP website. Figure 7-1 shows an example of the field mapping conducted by YRLSP. The remote sensing project yielded > 83% confidence that leafy spurge is correctly detected by remote sensing methods, so the final remote sensing maps are used as the primary data source for scoring the invasive species indicator.

Data to score this indicator are also collected by floating the entire focal segment of the Yampa River and noting instances of Russian olive and tamarisk observed in portions of the riparian area that can be seen from the channel. These observations are documented via photographs and notes, and observations of Russian olive and tamarisk are scored based on presence/absence of either species. In particular, a score of 0 is assigned if no Russian olive or tamarisk is observed on either bank within a riverscape, and 1 point is assigned if at least one individual is observed on either the left or right bank for either species. For example, if Russian olive is observed on one of the two banks in a riverscape, but tamarisk is not observed, the score is 1. If both Russian olive and tamarisk are observed on one bank, the score is 2. If both species are observed on both banks, the score is 4. Scores for these invasives range from 0 to 4 points.

Because the data collection and modeling methods were more rigorous for the leafy spurge data, these results are weighted more heavily than the other invasives to derive a final invasive species indicator score.

Figure 7-1. YRLSP Map of Leafy Spurge Cover Across Scorecard Focal Segment in 2020



7.2.2 Scoring Criteria

The scoring criteria outlined in Table 7-3 based on YRLSP leafy spurge mapping and qualitative field observations of Russian olive and tamarisk are used to rate the invasive species indicator. Scoring is mainly driven by leafy spurge data.

Table 7-3. Invasive Species Indicator Scoring Criteria

Grade	Description
A	No or only trace amounts (<1%) of leafy spurge present in the riparian area. No observations of Russian olive and/or tamarisk noted (invasives score of 0).
B	Low coverage (1-5%) of leafy spurge present in the riparian area. Infrequent observations of Russian olive and/or tamarisk noted (invasives score of 0-1).
C	Moderate coverage (6-25%) of leafy spurge present in the riparian area. Moderate number of observations of Russian olive and/or tamarisk noted (invasives score of 0-3).
D	High coverage (26-50%) of leafy spurge present in the riparian area. Frequent observations of Russian olive and/or tamarisk noted (invasives score of 2-4).
F	Very high coverage (51-100%) of leafy spurge present in the riparian area. Consistent to constant observations of Russian olive and/or tamarisk noted (invasives score of 4).

7.2.3 Results

Observations of tamarisk and Russian olive were relatively minimal throughout the study reaches. In riverscapes 17, 19, 22, and 24, neither species was observed along the banks during data-gathering floats. Observations of infrequent occurrences of Russian olive were made in riverscapes 18 and 20, and moderate occurrence was observed in riverscape 23. Notably, tamarisk was not observed in the entirety of the study reach, though it is important to note that data gathering was limited to the area that could be observed from the channel. In this respect, grades for the tamarisk and/or Russian olive sub-indicator were relatively high (Table 7-4); only riverscape 23 scored a C, and the remaining riverscapes scored As and Bs.

Conversely, analysis of publicly available leafy spurge data suggested extensive occurrence of the invasive throughout the each riverscape, except for the upper half of riverscape 18 and all of riverscape 17. Data for these locations were not available, but communications with the YRLSP team indicate that the observations in the middle of riverscape 18 are the most upstream known populations of leafy spurge in the area (P. Williams, personal communication 2022). Maps of ground observations regarding leafy spurge occurrence from the Yampa River Leafy Spurge Project indicate several areas of moderate to high coverage in riverscapes 19, 20, 23, and 24 interspersed with areas of low or trace coverage. Additional perspective gleaned from remotely sensed data suggest that occurrence of leafy spurge is particularly pervasive in many of the study reaches. By calculating the relative percent area occupied by pixels indicating the presence of leafy spurge to total floodplain area, leafy spurge coverage was further analyzed in addition to the mapped data (Figure 7-2). Results suggest that percent coverage ranges between approximately 13-30% of the total floodplain area (Figure 7-2). Scores specific to leafy spurge are thus notably poor in all but the furthest upstream areas of the Middle Yampa segment; whereas riverscape 17 and 18 earned A and B scores, respectively, no reach from 19-24 scored above a C, and reaches 20 and 22 earned D scores (Table 7-4).

Figure 7-2. Field Mapped and Remotely Sensed (RS) Leafy Spurge Coverage Across the Middle Yampa Segment

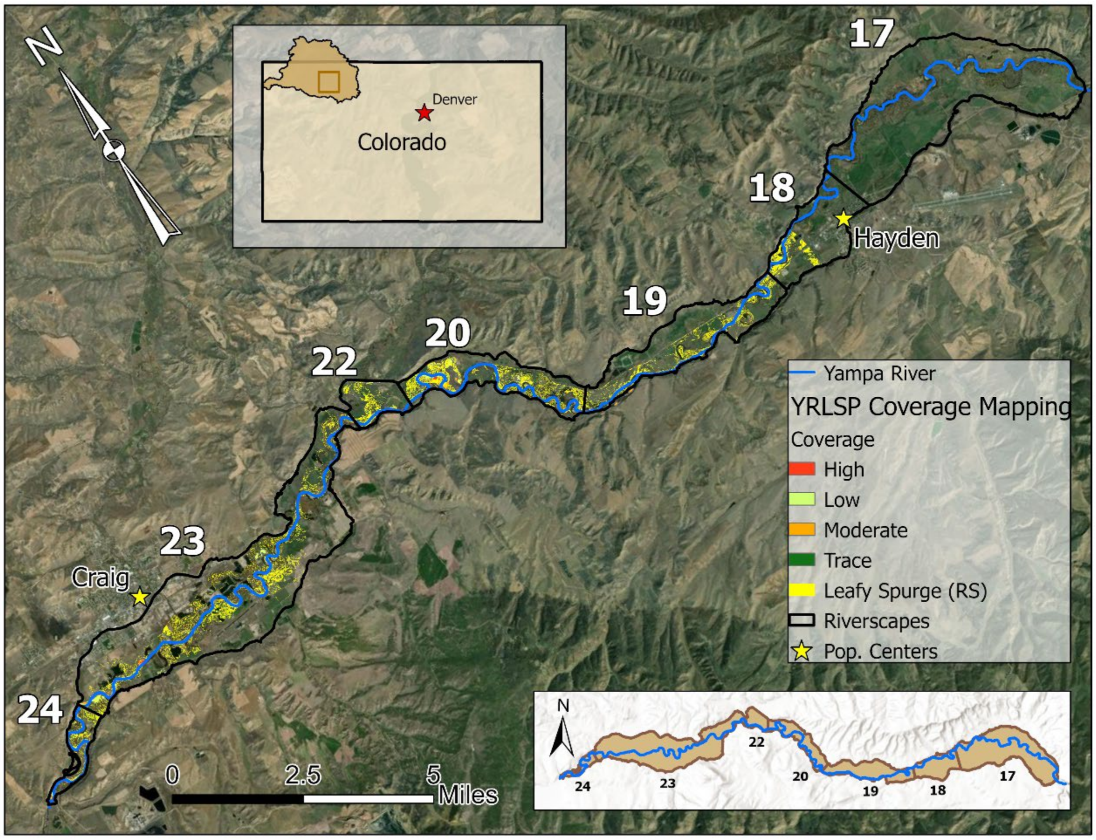


Table 7-4. Invasive Species Indicator Scores by Riverscape

Riverscape	Tamarisk/Russian Olive Score	Leafy Spurge Score	Invasive Species Score
Riverscape 17	A	A	A
Riverscape 18	B	B	B
Riverscape 19	A	C-	B-
Riverscape 20	B	D	C
Riverscape 22	A	D	C+
Riverscape 23	C	C-	C-
Riverscape 24	A	C-	C+

8.0 RIVER FORM

River form is defined as the river channel shape and geometry. It is directly influenced by the physical attributes of the watershed (e.g., geology, topography, hydrology), channel hydraulics, sediment transport, and local hillslope and floodplain uses (e.g., adjacent roadways, grazing). Biological drivers (e.g., riparian vegetation, large woody material, beaver activity, aquatic vegetation) influence river form as well, by altering hydraulics and erosional patterns. The Yampa River Scorecard evaluates river form holistically, using a single indicator referred to as **channel morphology**.

8.1 CHANNEL MORPHOLOGY INDICATOR

The channel morphology indicator is scored holistically and qualitatively considering planform shape (aerial shape), dimension (cross-sectional shape/size), and profile (slope). Quantitative measurements are used to inform qualitative scoring in some cases.

8.1.1 Data Sources and Evaluation Methods

A combination of remote sensing and field measurements are used to score the channel morphology indicator. Planform shape can be evaluated through remote measurement of valley confinement and parameters such as sinuosity. Comparison of historical and current aerial imagery can also be helpful. A stressor-based approach is also employed to evaluate channel morphology, with a component of the field floats that includes taking note of low-head dams, diversions, and bank and in-channel treatments that may impact grade (Appendix A).

The Scorecard effort acknowledges that channel morphology assessments that employ traditional metrics were conducted on river systems that had been long impacted by controls that reduce complexity, leading to the narrow view of rivers as channels having easily-measured forms. For the Scorecard, these metrics are used in the context of a progression from the past to the present, as well as evaluating where they fall on a continuum of stability. In this manner, channel form that falls outside of the natural continuum to be expected of a healthy river can be evaluated as indicative of a river that has some issues. The Scorecard public interface will explain these differences.

This indicator is scored using best professional judgement supported by the observations and measurements described above. Expert opinion is based on data collected and observed in the field, aerial imagery, and GIS spatial data to generate a single score for the channel morphology indicator.

8.1.2 Scoring Criteria

The descriptive, qualitative scoring criteria outlined in Table 8-1 are used to rate the channel morphology indicator. The criteria relate primarily to the presence of stressors and level of maintenance required to maintain functional river processes.

Table 8-1. Channel Morphology Indicator Scoring Criteria

Grade	Description
A	Planform, sinuosity, meander-wavelength to bankfull-width ratios, and variations are appropriate for a well-functioning river of this flow/sediment regime and landscape setting. There are no significant constraints to river planform or significant artificial changes in slope (e.g., dams, channelization, grade control structures). Channel geometry is within a range that is natural and appropriate for a well-functioning river in its process domain. The channel geometry is self-sustaining under natural channel processes and requires no maintenance.
B	Planform, sinuosity, meander-wavelength to bankfull-width ratios, and variations are within a range that is natural and suitable for a river of this flow/sediment regime and landscape position. Stressors are detectable but minimal management is needed to maintain functionality. Minor localized impacts exist that minimally affect channel entrenchment, capacity, or width-depth ratios.
C	Stressors on the river planform and/or sinuosity and/or wavelength-width ratios impact localized portions of the channel. Examples include reaches with short lengths of bank aromoring (decreased sinuosity) or reaches that have been slightly straightened (decreased wavelength-to-width ratios). Stressors are common along the reach and management is likely required to maintain functionality. Moderate impacts exist that significantly affect channel entrenchment, capacity, or ratios.
D	Widespread stressors impact the river planform, such as floodplain encroachment, hardened banks, or planform straightening. Major bank armoring and/or significant changes to sinuosity or meander wavelength are present, such as reaches with large (>3 feet) grade control structures and moderate planform changes. Active management and maintenance are required to maintain functionality. Widespread impacts exist that severely affect channel entrenchment, capacity, or width-depth ratios.
F	Widespread stressors cause severe impacts or changes to the planform and slope. Examples include anastomosed or meandering streams that were straightened or channelized, rivers with severe floodplain encroachment or armoring of banks, and streams with very large (>6 ft) grade control structures. Stressors are extensive throughout the reach and the level of impairment results in an inability to maintain characteristic function. Profound impacts exist with near-complete alteration of channel entrenchment, capacity, or width-depth ratios. Intensive or consistent active management and maintenance are required. Severe changes to slope are evident.

8.1.3 Results

The channel morphology indicator is evaluated through remote sensing analysis using aerial imagery and GIS spatial data, as well as qualitative field observations. Various morphological calculations were made to evaluate planform in the context of what would be expected for a river in the process domain of the Middle Yampa segment, including sinuosity and meander wavelength to channel width ratios (l/w). Fieldwork completed for the entire Scorecard project included stressor-based observations that are relevant for channel morphology.

Channel morphology scores are highest in riverscapes 17 and 20. In both riverscapes, the riparian ecosystem retains much of its natural character and the river appears well connected to the floodplain. Inhibitions to natural channel processes in these reaches are fairly minor: in-channel barriers are relatively minimal (Figure 5-1), as is armoring (Figure 9-1), enabling the maintenance of a channel planforms consistent with what would be expected of a river like Yampa throughout these riverscapes. Additional complexity features such as side channels and split flows are moreover indicative of a well-functioning river system. Prior reports have furthermore indicated the high geomorphic complexity and degree of connection between the channel and floodplain area present in riverscape 20 (Yampa IWMP 2021). The presence of stressors in a few locations, however, exerts a slightly controlling influence at particular locales. Still, sinuosity values and l/w ratios (Table 8-2) are within the natural range of variability for a mixed-load river, though it must be stated that the former is on the relatively lower side for what one would predict for an unconfined river stretch such as riverscape 17 (Schumm 1985, Nicoll and Hickin 2010). The meandering planform observed in both riverscapes 17 and 20 is also in the range of what would be anticipated using the stream evolution triangle for the hydrologic, lithologic, and biotic character of these stretches (Castro and Thorne, 2019). These two riverscapes therefore earn a channel morphology score of A (Table 8-3).

Table 8-2. Confinement, Sinuosity, and Meander Wavelength to Bankfull Width Ratio (l/w) by Riverscape

Riverscape	Confinement	Sinuosity	l/w
Riverscape 17	Unconfined	1.52	13.4
Riverscape 18	Partly Confined	1.32	20.9
Riverscape 19	Partly Confined	1.15	19.9
Riverscape 20	Partly Confined	1.50	13.6
Riverscape 22	Partly Confined	1.09	19.8
Riverscape 23	Unconfined	1.32	11.8
Riverscape 24	Confined	1.61	13.6

River morphology in riverscapes 19 and 23 is comparatively more impacted than riverscapes 17 and 20. Presence of armoring in riverscape 23 exerts a substantial stressor on the river, preventing natural channel processes in several locations (Figure 9-1). However, a relatively intact riparian forest in several locations in this riverscape drives a fairly high occurrence of large wood (e.g., Appendix A, Figures A-15 through A-18) and a diversity of active in-channel bar features (Figure 9-2), suggesting that a degree of natural character is retained. A fairly high prevalence of features such as side channels and split flows (Figure 5-1) moreover suggests that the river has the freedom to maintain active processes such as migration in many stretches throughout riverscape 23. Though l/w ratios are within the range of natural variability (8-14) for freely meandering, unconfined channels, sinuosity is rather low for a reach of this character (Table 8-2). For these reasons, this riverscape earns a channel morphology score of B (Table 8-3). In riverscape 19, armoring in the upper portions adjacent to human infrastructure reduces the ability of the river to maintain a natural planform. This likely drives the relatively low sinuosity and relatively high l/w ratios compared to natural ranges for partly confined rivers (Nicoll and Hickin 2010). However, in the lower parts of riverscape 19, the river is relatively more connected to its floodplain and stressors are more minimal, enabling morphological processes to retain more functionality. In these lower parts, a diversity of bar surfaces is present, as is relatively substantial large wood (Figure 9-2). Riverscape 19 therefore earns a channel morphology score of B- (Table 8-3).

The lowest morphology scores are for riverscape 18, 22, and 24. Stressors on morphology in riverscape 22, where the Elkhead Creek tributary enters the main stem Yampa River, are relatively minimal. Sinuosity values and l/w ratios here, however, are lower and higher, respectively, than natural ranges for a partially confined, mixed load river (Table 8-2). Complexity is also much lower than would be expected for a stretch of river containing a confluence with a major tributary; this likely speaks to a relatively high degree of alteration of the landscape surrounding the junction with Elkhead Creek. Riverscape 22 earns a channel morphology score of C for these reasons (Table 8-3). In contrast, the river in both riverscape 18 and 24 is substantially confined by human actions (armoring) (Figure 9-1), often to protect infrastructure (roads, railroads); features that are suggestive of a maintenance of natural processes are comparatively minimal. In the former, sinuosity and l/w ratios in the upstream portions are within predicted ranges; however, in the lower portions, the river is heavily modified, and l/w ratios are higher than the expected range of natural values for a partly confined river (Nicoll and Hickin 2010, Table 8-2). Riverscape 24 is the only naturally confined reach of the Middle Yampa segment, and sinuosity and l/w are within the range of natural variability. However, human stressors are present in a fairly extensive manner. These riverscapes earn a channel morphology score of C- (for riverscape 18) and a C (for riverscape 24) (Table 8-3).

Table 8-3. Channel Morphology Scores by Riverscape

Riverscape	Channel Morphology Score
Riverscape 17	A
Riverscape 18	C-
Riverscape 19	B-
Riverscape 20	A
Riverscape 22	C
Riverscape 23	B
Riverscape 24	C

9.0 STRUCTURAL COMPLEXITY

Structural complexity is defined as the degree of heterogeneity and physical composition of a stream that results from interactions between flow regime, sediment dynamics, and other factors. The more complex and heterogeneous the physical structure of a stream, the more enhanced the habitat for resident aquatic species. Structural complexity considers hydraulic characteristics (water depth and velocity patterns), bed and bank features, and substrate material. In scoring the indicators in this category, a concerted effort is made to integrate quantifiable records and observations from fieldwork conducted by educational partners. Two indicators are included in the structural complexity category: **macrohabitat** and **microhabitat**. The final structural complexity score is calculated as 75% macrohabitat and 25% microhabitat indicator scores.

9.1 MACROHABITAT INDICATOR

The macrohabitat indicator considers physical habitat relevant to fish and larger animals, including distribution and diversity of water depth, velocity, and physical cover, shape of bed and bank features, and other large physical structure provided by rock, wood, vegetation, etc. Macrohabitat includes cobble/sand bars, undercut banks, presence/absence of secondary channels/backwaters, and presence, extent, and quality of large wood.

9.1.1 Data Sources and Evaluation Methods

The following features that are important for heterogeneity and complexity within the channel are evaluated in the field, usually from a boat:

- Bedforms including riffles, runs, pools, and glides;
- Split flows (i.e., two narrow channels versus one wide channel);
- Secondary channels (count, GPS, presence of water yes/no);
- Point bars (characteristics: vegetated, cobble, gravel, sand; size);
- Residual pool depth (riffle crest depth minus deepest pool depth);
- Signs of beaver activity (chews, dams, side channel dams, bank dens);
- Presence, size, and quality of large wood;
- Reinforced bank length and type (GPS start and end of reinforced banks on both sides of channel and indicate material (concrete, car bodies, riprap, etc.);
- Undercut bank length; and
- Backwater areas.

Fieldwork to inform this indicator was completed during a 10-day field course in June 2022 coordinated in partnership with Colorado Mountain College. To the extent possible, these features were enumerated, representative photos are taken, and measurements are quantified and marked with a GPS device (Appendix A). These quantitative measurements feed into the quantitative scoring described in detail in Table 9-1.

9.1.2 Scoring Criteria

The scoring criteria outlined in Table 9-1 based on estimates of diversity of depth/velocity combinations, topographic complexity of beds and banks, and physical structure of the reach are used to rate the macrohabitat indicator.

Table 9-1. Macrohabitat Indicator Scoring Criteria

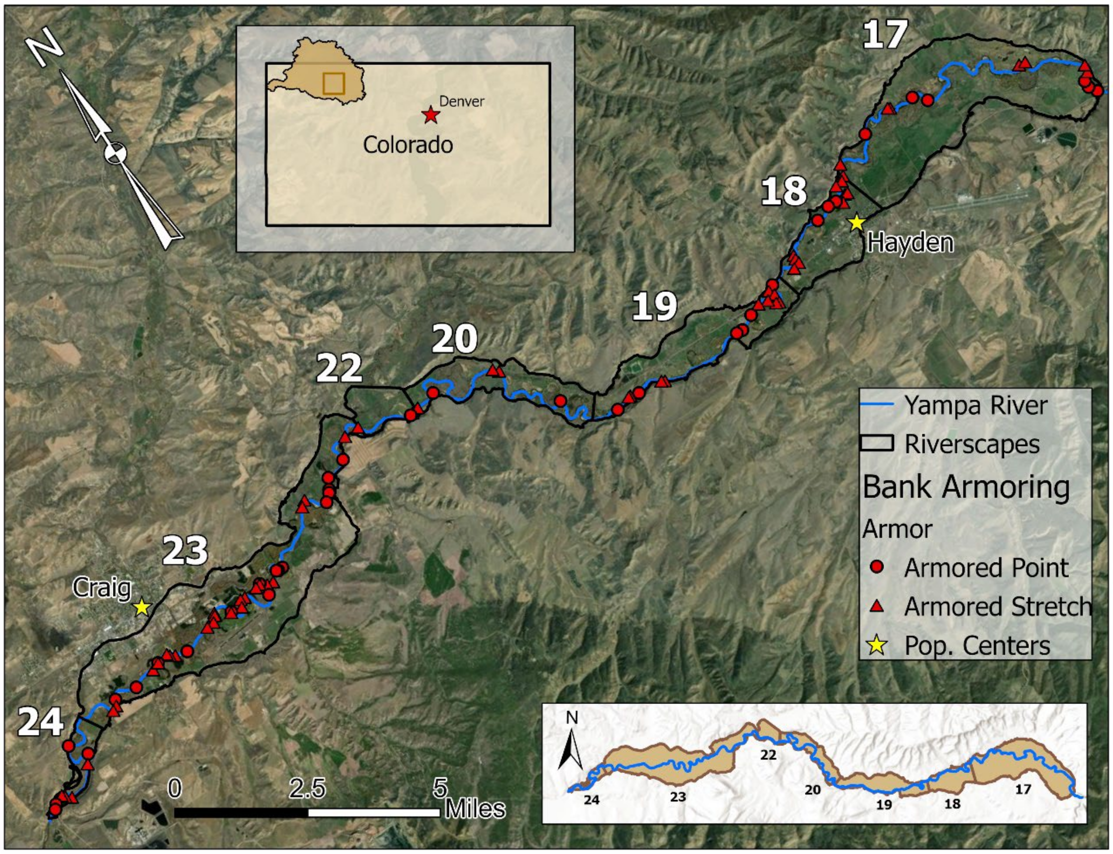
Grade	Description
A	Macro-scale structural heterogeneity is natural and appropriate for a well-functioning river in its process-domain. All velocity-depth combinations and structural components (features formed by wood, rock, vegetation, and debris dams/jams) are present in characteristic distribution.
B	Most typical velocity-depth combinations are present, but distribution of structural components (features formed by wood, rock, vegetation, and debris dams/jams) is slightly skewed due to dispersed stressors or minimal direct impacts. Pools provide adequate cover for fish and other aquatic organisms.
C	Some typical velocity-depth combinations or characteristic structural elements (features formed by wood, rock, vegetation, and debris dams/jams) are absent or limited. Pools provide some cover for fish and other aquatic organisms. Examples include reaches with increased pool/run habitat, lack of off-channel habitat, or skewed riffle-pool ratio. Reaches with artificial structure or hardened/revetted banks also fall into this category.
D	Some typical velocity-depth combinations or characteristic structural elements (features formed by wood, rock, vegetation, and debris dams/jams) are absent, making the reach uncharacteristically homogeneous. Pools may provide minimal cover for fish and other aquatic organisms. Examples include reaches with graded or heavily armored banks, or with features that are frequently limited by inundation or low flow.
F	Homogeneous form with uniform velocity-depth pattern, lack of physical structure, and lack of pools. Examples include reaches with severely homogenized physical characteristics such as unnatural plane-bed morphology.

9.1.3 Results

Macrohabitat was scored holistically by the consideration of the variables outlined in the grading scheme above, several of which comprise criteria considered for additional indicators herein. Rather than an indicator of redundancy, this instead illustrates the broad, integrative nature of the river landscape in setting the habitat template. Data evaluated here was gathered from field floats of the riverscapes in consideration and informed by review of current and historical aerial imagery.

Bank armoring (e.g., Appendix A, Figures A-4 through A-9) is likely the most consistently detrimental factor with regards to relatively diminished structural heterogeneity (and thus macrohabitat). Bank armoring contributes to reach homogenization and increased resistance to the drivers of river complexity, mainly channel migration and the formation of secondary channels. Armoring is particularly pervasive in reaches 18, 23, and 24 (Figure 9-1), where 25-33% of the channel length is reinforced via a variety of mechanisms: traditional riprap using large rocks, emplacement of a mélange of concrete debris, or, on occasion, "Detroit riprap" – the lining of riverbanks with old automobiles and appliances. The occurrence of relatively more extensive bank reinforcement in these riverscapes is not surprising given the proximity to population centers (Hayden, Craig) and related infrastructure. In contrast, riverscapes 17 and 20 are notably lightly armored; again, this is relatively unsurprising, as these are stretches of river that flow through conservation areas (The Nature Conservancy's Carpenter Ranch and Yampa River State Wildlife Area, respectively).

Figure 9-1. Bank Armoring Across the Middle Yampa Segment by Riverscape



Likely as a function of this relatively light armoring, riverscapes 17 and 20 also have extensive occurrences of features indicative of complexity such as backwaters and side channels/split flows (Figure 5-2). As mentioned above, this may result from the additional "freedom" of the river to migrate across the floodplain in these sparsely armored reaches. Interestingly, despite the fairly frequent occurrence of armoring in reach 23, complexity features are somewhat abundant; this is perhaps due to the preservation of the natural floodplain ecosystem in many areas. Relatedly, there is relatively extensive occurrence of large wood and bar surfaces in reach 23 (Figure 9-2), both indicators of comparatively natural riverine complexity.

Wood and bar surfaces are additionally extensive in riverscapes 19 and 20, and moderately so in riverscape 17. Similarly, signs of beaver activity are frequent in these riverscapes, as well as moderately frequent in riverscapes 22 and 23 (Figure 9-3, Appendix A Figures A-1 through A-3). Again, this is likely due to the occurrence of a fairly intact riparian ecosystem throughout areas. These various indicators of complexity (e.g., beavers, wood, side/split channels, backwaters, bars) are again notably low in riverscapes 18 and 24, the most highly armored of the areas in the Middle

Yampa River segment. All indicators of complexity in riverscape 22 are moderately frequent or relatively sparse despite low armoring; this is perhaps a function of this reach's shorter overall length as well additional confounding factors presented by the confluence with Elkhead Creek (which occurs in riverscape 22). Scores for the macrohabitat in each riverscape are provided in Table 9-2.

Figure 9-2. Locations of Bar Surfaces and Large Wood by Riverscape

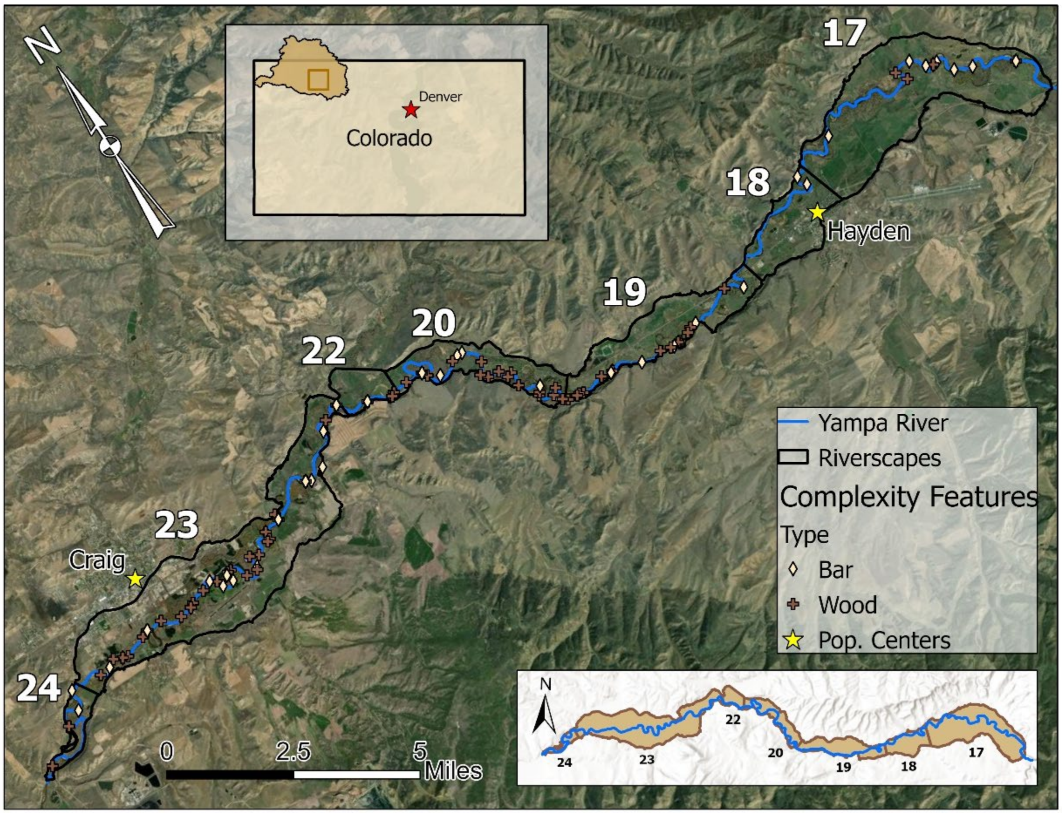
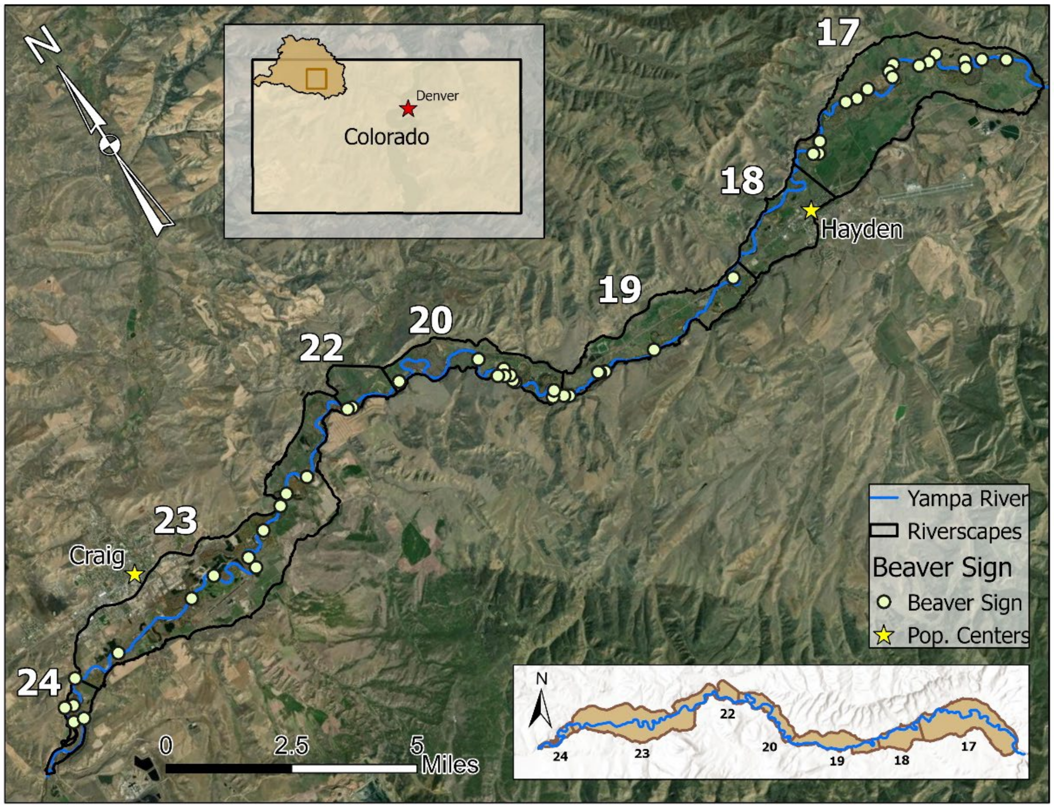


Table 9-2. Macrohabitat Scores by Riverscape

Riverscape	Macrohabitat Score
Riverscape 17	A
Riverscape 18	D
Riverscape 19	B
Riverscape 20	A-
Riverscape 22	B-
Riverscape 23	C+
Riverscape 24	D

Figure 9-3. Beaver Sign by Riverscape



9.2 MICROHABITAT INDICATOR

The microhabitat indicator considers physical habitat relevant to small aquatic species such as benthic macroinvertebrates and larval fish, particularly the availability of interstitial spaces among the river bed substrate, degree of embeddedness, armoring, proportion of fine sediment, algae cover, and patches of organic material or detritus accumulations.

9.2.1 Data Sources and Evaluation Methods

The microhabitat indicator is scored in the field through visual observations of embeddedness and presence/absence of algae cover. Embeddedness measures the degree to which gravel and cobble substrates are surrounded by fine sediment. It relates directly to the suitability of the stream substrate as habitat for macroinvertebrates, fish spawning, and egg incubation.

Embeddedness measurements occur in riffles only. Embeddedness is measured by picking up particles of gravel or cobble with the evaluator's fingertips at the fine sediment level. The particle is pulled out of the bed and the percent of that particle that was buried by sediment is estimated (NRCS 2017). All measurements of percent embeddedness within each riverscape are averaged for a final embeddedness percentage by riverscape.

9.2.2 Scoring Criteria

The scoring criteria outlined in Table 9-3 based on field observations of interstitial space availability, bed armoring, embeddedness, and algae in riffles are used to rate the microhabitat indicator.

Table 9-3. Microhabitat Indicator Scoring Criteria

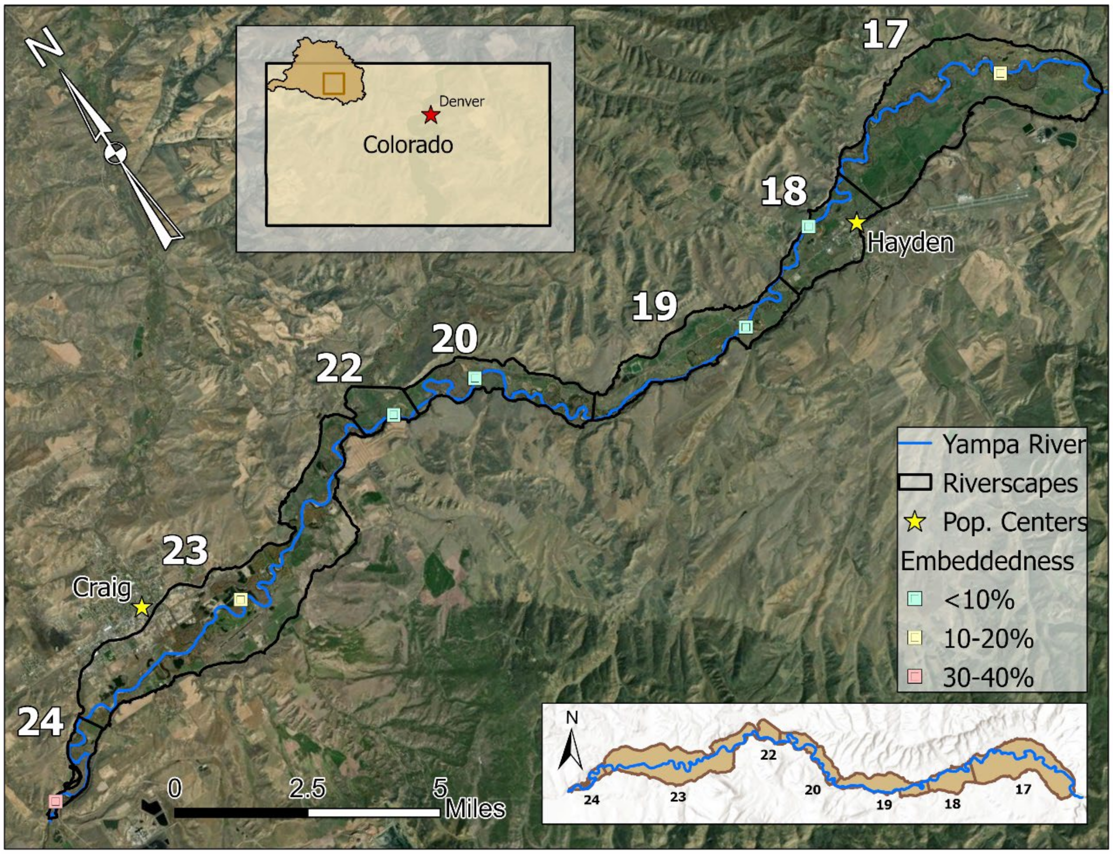
Grade	Description
A	Micro-scale structural heterogeneity is natural and appropriate for a well-functioning river in its process-domain. Interstitial spaces appropriate for natural geographic conditions.
B	All aspects of micro-scale structural diversity are present, but distribution of features is skewed due to dispersed stressors or minimal direct impacts. Examples include reaches with mild fine sediment deposition or slightly decreased interstitial space (mild embeddedness, 10-20%) for either cobble- or gravel-bed reaches, depending on natural geographic conditions.
C	Some aspects of micro-scale structural diversity are lacking or limited. Examples include reaches with altered bed material distribution, patches of armoring, increased cover of persistent algae/aquatic vegetation, decreased detritus/organic accumulation patches, or moderate embeddedness (20-30%) for either cobble- or gravel-bed reaches, depending on natural geographic conditions.
D	Some aspects of micro-scale structural diversity are lacking or severely limited, making the reach uncharacteristically homogeneous. Examples include reaches with widespread armoring, persistent algae/aquatic vegetation in riffles, lack of any detritus/organic accumulation patches, or severe embeddedness (30-40%) for either cobble- or gravel-bed reaches, depending on natural geographic conditions.
F	Completely static or homogeneous armored micro-scale physical structure. Examples include gravel- or cobble-bed streams that are aggrading with fine material (embeddedness >40%) or choked with algae, alluvial streams unnecessarily scoured to bedrock, or grouted/hardened artificial streambeds.

9.2.3 Results

Data to score this indicator were collected via field visits to illustrative locations with reliable access in each riverscape and observing presence/absence of algae cover, as well as evaluating embeddedness at riffles co-located with macroinvertebrate monitoring locations, plus a few additional opportunistic locations. Embeddedness is evaluated following the methodology described above.

Embeddedness was lowest at measured riffles in riverscapes 18, 19, and 20 (Figure 9-4). Given the relatively low scores for riverscape 18 in other indicators, its inclusion here is somewhat surprising; however, the location evaluated for embeddedness is in the upper reaches of 18, which is still within the boundaries of The Nature Conservancy's Carpenter Ranch. Low values of embeddedness in riverscapes 19 and 20 track with the preservation of these reaches within Yampa River State Wildlife Area. Relatively low embeddedness values of 10-20% were measured in riverscape 17 and 23, consistent with the relatively natural character of these reaches.

Figure 9-4. Embeddedness Locations and Ranges by Riverscape



The highest embeddedness scores were recorded in riverscape 24 and were 30-40%. This is in line with the similarly low scores in other indicators for this riverscape. Interestingly, embeddedness values are consistently low from riverscapes 18-22, then increase relatively in 23 and 24, a spatial trend that is perhaps reflective of the role of Elkhead Creek (which flows into the Yampa in riverscape 22) in supplying the excess fine sediment that results in higher embeddedness values.

Algal cover was substantial throughout the riverscapes within the Middle Yampa segment during low flow conditions (July through October), but slightly less prevalent in riverscapes 18 and 20. A river with significant algae growth in low water times is relatively typical; algae can take hold and establish when flows are low and then they are typically scoured away due to high flows in the spring. The high flows scour algae and act as a reset each year. During June fieldwork, algal cover was not as prevalent, indicating that this somewhat typical cycle is occurring on the Middle Yampa River. Scores for the microhabitat indicator are presented in Table 9-4.

Table 9-4. Microhabitat Scores by Riverscape

Riverscape	Microhabitat Score
Riverscape 17	B
Riverscape 18	A-
Riverscape 19	A-
Riverscape 20	A
Riverscape 22	A-
Riverscape 23	B-
Riverscape 24	D

10.0 BIOTIC COMMUNITY

Biotic community is defined as the health of resident aquatic biota including microbes, periphyton (attached algae), macrophytes (aquatic plants), macroinvertebrates (aquatic insects), fish, amphibians, and any other organism that is part of the aquatic biological community for all or part of its life history. There are two indicators within the biotic community category: **macroinvertebrates** and **native fish**. The final biotic community score is calculated as an average of the macroinvertebrates and native fish indicator scores. Information about sport fish is covered in the River Uses and Management attribute of the Scorecard.

10.1 MACROINVERTEBRATES INDICATOR

Benthic macroinvertebrates can be used as indicators of both water quality and the health of the biotic community. Refer to Section 4.4 for details and scores related to this indicator.

10.2 NATIVE FISH INDICATOR

Fish population monitoring, typically conducted via electrofishing surveys, is used to determine fish species composition (including relative abundances of species), density estimates, age or size class distribution, and other metrics related to the health of the fishery. Due to the paucity of comprehensive data in the Scorecard focal segment, the native fish indicator is focused on percent native fish and presence of Mountain Whitefish and the "Three Species." The "Three Species" are Bluehead Sucker, Flannelmouth Sucker, and Roundtail Chub. These species are not currently listed under ESA, but they have similar ecological requirements and are imperiled throughout their collective geographic range.

10.2.1 Data Sources and Evaluation Methods

Many of the fish electroshocking efforts in this region, particularly those conducted by US Fish and Wildlife Service (USFWS), have been focused on invasive species removal (for species such as Northern Pike, Smallmouth Bass, and White Sucker). Colorado College professor Dr. Brian Linkhart obtains a permit through Colorado Parks and Wildlife (CPW) for electroshocking a long-term monitoring site in the Middle Yampa River segment that has been sampled for 14 years over a 17-year period (2003-2019), generally in the fall (early September), as part of an undergraduate class. Scoring the native fish indicator for the Scorecard relies mainly on this dataset. The long-term monitoring reach is located between Hayden and the confluence of Elkhead Creek in the vicinity of Yampa River State Wildlife Area (riverscape 19). Some historical data exist for riverscapes 17 and 20 as well, but these data are more focused on non-native fish removal efforts, and are therefore biased to record those species more frequently instead of providing some estimation of species abundance and diversity. A low level of confidence is associated with scores from all riverscapes except riverscape 19 for this reason.

10.2.2 Scoring Criteria

The scoring criteria outlined in Table 10-1 based on presence and proportions of native species are used to rate the native fish indicator. This scoring scheme is based on the fisheries evaluation conducted for the Yampa IWMP remote assessment (Yampa IWMP 2021). It acknowledges that nearly all of the Yampa's riverscapes contain impacted fisheries; any riverscapes that earn an "A" grade are still highly modified compared to historical conditions. However, the goal of this scoring system is to differentiate between riverscapes on a relative scale. Had the historical condition of robust, native fisheries been used for the "A" grade, no differentiation would be possible, because all riverscapes would have low scores. The use of an altered baseline condition allows the prioritization of riverscapes and the opportunity to select individual riverscapes for future adaptive management and research activities. In transitional riverscapes, the fish community is composed of coldwater and warmwater species, and the scoring is adjusted to reflect this. For example, a small proportion of salmonids does not indicate impairment in riverscapes in the transitional Scorecard focal segment (Yampa IWMP 2021).

Table 10-1. Native Fish Indicator Scoring Criteria

Grade	Description
A	The reach supports all of the expected native species for the given watershed location. In coldwater riverscapes, Colorado River Cutthroat Trout, Mountain Whitefish, Mottled Sculpin, and Mountain Sucker are expected. In warmwater riverscapes, The Three Species (Bluehead Sucker, Flannelmouth Sucker, and Roundtail Chub), Mountain Sucker, Colorado Pikeminnow, and Speckled Dace are expected. Nonnative species such as Northern Pike, Smallmouth Bass, and White Sucker are not common. The percentage of native species is generally greater than 50%.
B	The reach supports a majority of the expected native species for the given watershed location. In coldwater riverscapes, Colorado River Cutthroat Trout, Mountain Whitefish, Mottled Sculpin, and Mountain Sucker could be expected. In warmwater riverscapes, The Three Species (Bluehead Sucker, Flannelmouth Sucker, and Roundtail Chub), Mountain Sucker, Colorado Pikeminnow, and Speckled Dace are expected. Nonnative species such as Northern Pike, Smallmouth Bass, and White Sucker are present but not common. The percentage of native species is generally greater than 20%.
C	The reach supports some expected native species for the given watershed location. In coldwater riverscapes, some or all of the native salmonids may have been replaced with Brook Trout, Brown Trout, and/or Rainbow Trout, but the naturalized populations are robust. Mottled Sculpin are expected. In warmwater riverscapes, some of the native warmwater species listed above are present. Mottled Sculpin and Speckled Dace are also expected. Nonnative species are common, and native species comprise 10-20% of the fish community.
D	The reach supports few or no native fish, or the fishery exhibits a highly degraded condition. In coldwater systems, salmonids are expected, but in low densities. Mottled Sculpin or Speckled Dace may be present. In warmwater riverscapes, The Three Species (Bluehead Sucker, Flannelmouth Sucker, and Roundtail Chub), Mountain Sucker, and Colorado Pikeminnow are largely or entirely absent. Speckled Dace may be the only native warmwater species present. Nonnative species are common and abundant. Native species comprise less than 10% of the fish community.
F	The reach does not support native fish, and/or the fishery exhibits a highly degraded condition. In coldwater systems, salmonids are absent or present in low densities, and Mottled Sculpin and Speckled Dace are absent. In warmwater

	riverscapes, The Three Species (Bluehead Sucker, Flannelmouth Sucker, and Roundtail Chub), Mountain Sucker, and Colorado Pikeminnow are absent. Nonnative species dominate, and native species comprise less than 5% of the fish community.

10.2.3 Results

Results for the native fish indicator are provided in Table 10-2 and described here. Unfortunately, no data are available for riverscapes 18, 22, 23, and 24.

Data from just upstream of the Highway 40 bridge (riverscape 16) is used as a proxy for scoring riverscape 17. These data consist primarily of nonnative fish removal data from 2000, 2012, 2015, 2017, and 2019. Species reported are almost all nonnatives except Mottled Sculpin and Speckled Dace in 2000 and two Flannelmouth Suckers in 2012. All trout are nonnative Brown Trout and Rainbow Trout. Recent (2019-2022) anecdotal reports of fishing directly upstream of this riverscape identified Northern Pike, Rainbow Trout, Brown Trout, Cuttbow Trout, and Mountain Whitefish, with trout being the most common salmonids but Mountain Whitefish also caught consistently. Based on these data, this riverscape earns a score of C-.

Riverscape 19 has the most data due to Professor Linkhart's class surveys. Species include some (though limited) instances of Flannelmouth Sucker, Roundtail Chub, and Bluehead Sucker. Surveys also produced Mountain Whitefish, Mottled Sculpin, and Speckled Dace. The percentage native species is greater than 50% in most recent years, but is composed almost entirely of Mottled Sculpin and Speckled Dace, earning riverscape 19 a score of C+. However, as a result of collection methods, larger-bodied species such as trout and whitefish are likely underrepresented in the samples.

Data collected in riverscape 20 are exclusively the result of nonnative removal efforts between 1989-2003. Predominantly captured were northern pike and white sucker, and the only trout observed were rainbow trout. In late 1980s/early-mid 1990s, some flannelmouth sucker and mountain whitefish were also observed. Smallmouth bass were observed in 2003. These data earn riverscape 20 a score of D.

It is possible that scores for riverscape 17 and riverscape 20 would improve slightly with data collection efforts tailored toward community characterization; however, the fishery in these riverscapes is significantly impaired due to an overabundance of nonnative species.

Table 10-2. Native Fish Indicator Scores by Riverscape

Riverscape	Native Fish Score
Riverscape 17	C-
Riverscape 18	NA
Riverscape 19	C+
Riverscape 20	D
Riverscape 22	NA
Riverscape 23	NA
Riverscape 24	NA

11.0 OVERALL RIVER HEALTH AND FUNCTION SCORE

Upon assigning scores for each indicator and category to each riverscape within the Scorecard focal segment, the individual category scores are integrated to derive a final river health and function score for each of the 7 riverscapes within the 39-mile segment of the Yampa River. The percent contributions of each river health and function category are provided in Table 11-1. A weighted average by riverscape area is then calculated to yield a final segment score for the River Health and Function attribute area.

Table 11-1. Percent Contribution to Overall River Health and Function Score by Category

Category	Percent
Flow Regime	20
Sediment Regime	5
Water Quality	15
Habitat Connectivity	5
Riverscape Connectivity	10
Riparian Condition	20
River Form	5
Structural Complexity	15
Biotic Community	5

The final river health and function scores for the Middle Yampa segment are provided in Table 11-2, organized by indicator and riverscape. **Weighting the cumulative scores for each riverscape by river length yields an overall ecological health and function score of B for the entire Middle Yampa River focal segment**.

The Middle Yampa River segment as a whole remains remarkably healthy in several aspects related to material transport, reflective of the lack of alteration to much of the river's natural ability to transfer sediment and nutrients through the landscape. Scores for sediment transport are consistently very good to excellent, as are many of the water quality parameters except temperature, especially pH, DO, nutrients, and metals. Excellent macroinvertebrate community scores further reflect the overall health of the river in terms of water quality and sediment transport.

Temperature, however, remains poor in the upper riverscapes of the Middle Yampa segment; poor fishery scores can perhaps be connected these poor temperature scores in the upper reaches. Opportunities for improvement exist and are being implemented by the City of Steamboat Springs and others.

Overall, the most extensive opportunities for improvement to the health of the Middle Yampa River segment are related to riparian condition and riverscape connectivity. As the former is rather dependent on the latter, improvements in connectivity – such as removal of floodplain infrastructure that reduces the ability of the river to access its floodplain or commitment to limiting future development of such infrastructure – may serve to improve riparian condition. Additional opportunities for improvement of riparian health may also exists such as the maintenance and/or restoration of a natural riparian buffer along the riverbanks.

In terms of patterns between riverscapes, it is clear that the Yampa River is most healthy in those reaches that are either preserved in one way or another, either by The Nature Conservancy (riverscape 17) or as a state wildlife area (riverscape 20), or where alterations to the floodplain have been minimal (riverscape 22, where all of the southern bank of the river retains much of its natural character). The best opportunities for improvement to riverine health exist in riverscapes that are home to the Middle Yampa's largest towns – Hayden in riverscape 18 and Craig in riverscape 23.

Overall, the Yampa remains a relatively healthy river, especially compared to its peers – both in the state of Colorado and throughout the Colorado River Basin. Despite this assessment, ample potential for improvement does exist – management that seizes such opportunities for progress will thus help to enable the Yampa to move forward into the future as a flagship river for riverine health. The authors of this report encourage you to visit https://yampascorecard.org/ to learn more about the Yampa River Scorecard Project.

Table 11-2. Middle Yampa Segment Ecological Health and Function Scores by Indicator and Riverscape

	Segment		Middle Yampa River Segment						
	Riverscape		17	18	19	20	22	23	24
	Length (miles)		8.29	3.05	5.34	6.04	2.15	10.72	3.3
	Riverscape Area (square miles)		7.9	2.03	3	2.42	0.85	10.43	0.64
Indicator	**Variable**	**Scoring Weight**							
Flow Regime	Hydrograph		76	82	76	82	88	88	88
	Snowpack		76	76	76	76	76	76	76
	Flow Regime	**20%**	76	81	76	81	87	87	87
Sediment Regime	**Sediment Transport and Continuity**	**5%**	92	92	95	95	95	82	82
Water Quality	Temperature		65	65	65	65	85	85	85
	Dissolved Oxygen		95	95	95	95	95	95	95
	pH		95	95	95	95	95	95	95
	Macroinvertebrates		88	88	88	88	88	88	88
	Nutrients		85	85	85	85	92	92	92
	Metals		95	95	95	95	95	95	95
	Water Quality	**15%**	87	87	87	87	92	92	92
Habitat Connectivity	Aquatic Habitat Connectivity		82	82	95	95	92	76	65
	Terrestrial Habitat Connectivity		85	85	76	85	95	76	95
	Habitat Connectivity	**5%**	84	84	86	90	94	76	80
Riverscape Connectivity	**Riverscape Connectivity**	**10%**	76	65	76	85	95	76	95
Riparian Condition	Vegetation Structure and Complexity		82	80	80	81	80	79	77
	Invasive Species		95	85	82	76	78	72	78
	Riparian Condition	**20%**	83	81	80	81	80	78	77
River Form	**Channel Morphology**	**5%**	88	65	82	88	76	82	65
Structural Complexity	Macrohabitat		95	65	85	92	82	78	65
	Microhabitat		85	92	92	95	92	82	65
	Structural Complexity	**15%**	93	72	87	93	85	79	65
Biotic Community	Macroinvertebrates		88	88	88	88	88	88	88
	Native Fish		72		78	65			
	Biotic Community	**5%**	80	88	83	77	88	88	88
	Weighted River Health Score	**100%**	84	79	82	85	87	83	82

12.0 REFERENCES

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APPENDIX A

PHOTO COMPILATION

Figure A-1. Beaver bank lodge in riverscape 20.

Figure A-2. Beaver sign at the base of floodplain cottonwoods in riverscape 19.

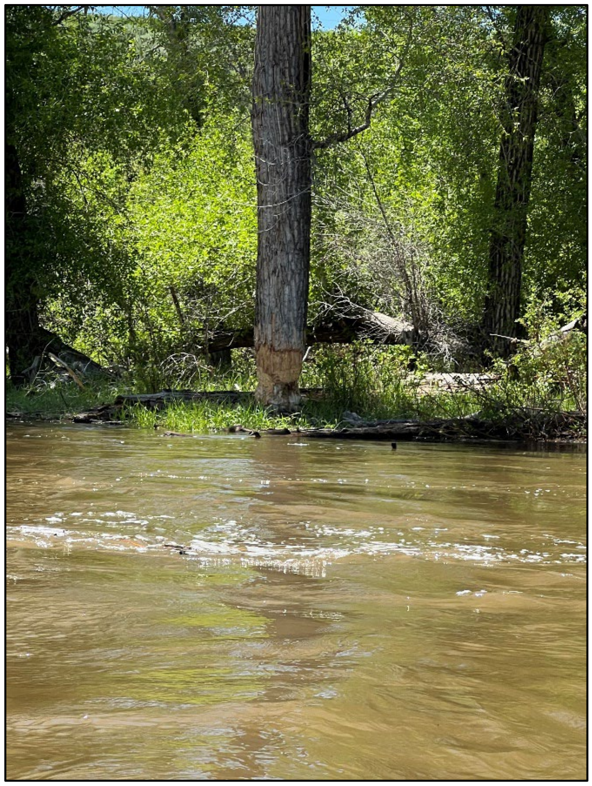

Figure A-3. Beaver sign.

Figure A-4. Bank armoring with large boulders.

Figure A-5. Bank armoring to protect railroad infrastructure.

Figure A-6. Bank armoring with old automobiles and other trash.

Figure A-7. Bank armoring with rootwads and large boulders.

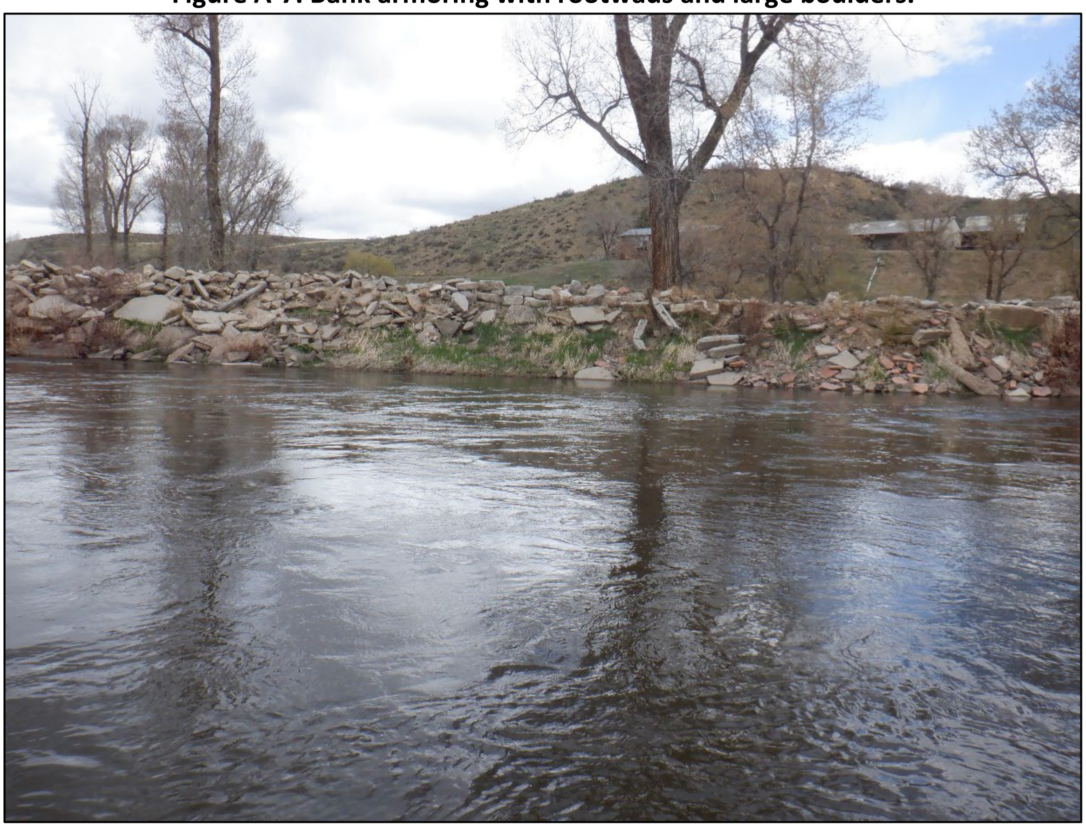

Figure A-8. Bank armoring with concrete.

Figure A-9. Bank armoring with heavy plastic.

Figure A-10. Bank erosion on the outer bend characteristic of a health meandering river.

Figure A-11. More healthy bank erosion.

Figure A-12. Gravel bar indicative of a healthy sediment regime.

Figure A-13. Gravel bar (again, suggestive of a healthy sediment regime).

Figure A-14. Gravel bar.

Figure A-15. Large wood accumulation on a mid-channel bar.

Figure A-16. Large wood.

Figure A-17. Large wood accumulation.

Figure A-18. Large wood.

APPENDIX B

TECHNICAL MEMORANDUM: YAMPA SCORECARD SEGMENT RIPARIAN MAPPING METHODS AND RESULTS (DECEMBER 10, 2021)